SCIENCE REDISCOVERS GOD

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OR

THE THEODICY OF SCIENCE

BY

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DEDICATED

IN GRATEFUL FRIENDSHIP AND ESTEEM TO

PRINCIPAL D. S. CAIRNS

WHO BY HIGHER PATHS HAS REACHED

A FULLER AND NOBLER FAITH

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SCIENCE REDISCOVERS GOD

CHAPTER I.—INTRODUCTORY

THE NECESSITY FOR A COMPREHENSIVE AND CATHOLIC VIEW OF LIFE

"Certainly a little philosophy inclineth man's mind to atheism, but depth in philosophy bringeth men about to religion, for when the mind of man looketh upon secondary causes scattered it resteth in them, but when it beholdeth them confederate and knit together it flieth to providence and Deitie."—F. BACON.

DURING the last centuries men of science have been strenuous and faithful workers, their conquests have been great, their harvests have been golden, yet it seems to me that they have been content with rather one-sided and short-sighted views of things, and that they have never reaped the full benefit of their victories, simply because they have never *consolidated* them. With consolidation and integration, with a comprehensive many-sided survey of the scientific position to-day, we shall find that Science has not only conquered the Earth, but is already besieging the ramparts and battlements of Heaven. But there must be consolidation, integration, width of survey. If we are content to consider what has been done and won separately

under certain artificial though convenient categories, such as osteology, geology, history, we get only the broken arcs of truth and fail to realise that the arch stretches from the material to the spiritual—from Earth to Heaven. If we study only the single threads of the web of life we never can discern its divine pattern.

An acute and courageous thinker, Principal Iverach, wrote thus: "Suppose a man to be led around the whole round of physics as it is presented to him at any of our well-equipped universities and to have acquired a well-grounded knowledge of the field of physics, what is his impression of it? It seems to me that the first thing he ought to do would be to touch mother earth once more. The unity of the world has been attenuated in his mind into a number of separate aspects. He has conception of a number of separate sciences, and of a world which so far corresponds to each abstract science, but not to a world which corresponds to the unity which underlies them all." And again: "When we unite the results of physics and chemistry we reach a fuller view of reality than when we look at the world with the eyes of each separately." Emerson expressed a similar view, saying that "the lesson of life . . . is to resist the usurpation of particulars to penetrate to their catholic sense"; and Goethe agreed,

> "Willst du in Unendlichen streiten
> Geh nur in Endlichen nach *allen* Seiten."

Certainly it is necessary that specialists should focus their vision on small fields, but if Science is to attain

to any large vision of truth there must be catholicism as well as specialism, and it is the fractional way in which Science is taught to-day by specialists with a limited intellectual horizon that makes it seem so dull and arid to many imaginative minds, and that often gives it a pessimistic and materialistic outlook. The ordinary layman is not a specialist: he is not concerned with the details and aims of any one science: he wants something to enlarge and deepen his intellectual life, and to move his spiritual imagination, and this can be best given him by a comprehensive presentation and illumination of life from many sides by many sciences.

The world seen from only one side is seen falsely. If a man view life only from the standpoint of osteology he will live among skeletons, if only from the standpoint of comparative anatomy he will squat on a branch with the apes, if only from the standpoint of chemistry he may believe with Carl Vogt that thought is a secretion of the brain as bile a secretion of the liver. If he study only endocrinology he may imagine that evolution can be altered by the administration of endocrines; if he be purely pathologist he may conceive of his heart as a muscular bag in a jar of methylated spirits. Life is a vital web, not a rag-heap; and we cannot unpick the web and yet preserve its larger vital significances.

Even in the practical applications of scientific facts it is only by conspiracies of the sciences that the larger discoveries have been made. Mathematics in the hands of that great genius Clerk Maxwell pointed the way

to wireless. Ultra-violet therapeutics had their origin in Newton's prism, Perkin's discovery of coal-tar dyes assisted Koch to convict the tubercle bacillus. Pasteur's researches in fermentation were the foundation of Lister's antiseptic surgery. To-day the physician consults with the pathologist, the pathologist with the bacteriologist, the bacteriologist with the bio-chemist, and all practical science is collaborative and co-operative. How wide and yet intimate the inter-relations of things are, we are ever more discovering. The tides are incomprehensible till we lift our eyes to the moon. The electrons leaping and clashing in the atoms of the sun give colour to the rainbow. We cannot really understand a green leaf till we surprise the sunbeams busy in its chlorophyll. We comprehend a lily better when we have dissected a worm. The field of a microscope extends to the Milky Way, and the vacuole pulsing in the amœba throbs in rhythm with the heart of a man. Have not even the unscientific poets discerned that Seven snowdrops sister the Pleiades—that we cannot pluck a flower without troubling of a star?

But the *particular* point I wish to make is not only that all things in the world afar to each other linked are; but also that a comprehensive and catholic and many-sided outlook and inlook brings us near to the warm heart of reality, and shows us "every common bush afire with God." Not only are all things linked, but by integrating the linkages widely enough so as to get a *tout ensemble* we get at least a glimpse of Him "in

Whom we live and move and have our being." A great poet and thinker, despised to-day by decadent critics and poetasters, once wrote:

> "Flower in the crannied wall,
> I pluck you out of the crannies;
> I hold you here, root and all, in my hand,
> Little flower—but *if* I could understand
> What you are, root and all, and all in all,
> I should know what God and man is."

and it will be my endeavour in these chapters, by looking at some of man's wide material relations and linking them together, to show something of what God and Man is.

So big a thing is Man as to be undefinable. He connotes every word in every dictionary and subsumes the light of every star. The very word "man" suggesting in itself no definition is a confession of undefinability, and only by orienting man in large relationships can we get any kind of idea of his material and spiritual stature. I shall therefore make no endeavour to deal exhaustively or fully with him under any one category such as anatomy, physiology, or physics. Rather I shall try, with the mutual assistance of many sciences, to show the marvel and mystery of his body, and the immortality and divinity of his soul. I shall try to make his dead bones live. And if any one rebuke me, and say that science ought not to be mixed up with poetry and religion, I shall reply that I challenge any rational man to divide and insulate them. Science to-day, regarded *en tout ensemble*, is magnificently imaginative, radiantly poetical, and radically religious. It is im-

possible to-day to separate the visible and the invisible, the physical and the metaphysical, and any science to-day that is catholic, courageous, and consistent, must discern in matter rational Will, and behind Will infinite Power and Wisdom.

CHAPTER II

MAN REGARDED THROUGH A TELESCOPE

"The whole frame of nature bespeaks an intelligent author, and no rational inquirer can after serious reflection suspend his belief a moment with regard to the primary principles of general Theism and religion."—D. HUME.

"The exquisite structure of the sun, the planets, and the comets could not have had their origin but by the plan and absolute dominion of an intelligent and powerful being."—NEWTON.

LET us now regard Man from the standpoint of the oldest science in the world—the science of astronomy. What view do we get of Man when we orient him amid the stars and examine him with a telescope? What has astronomy to say about his cosmic origin, and his sidereal orientation, and his planetary abode?

Amid the stars he is difficult to find and even on his own planet he is as dust. The astronomers tell us the Earth on which Man lives is in the midst of some twenty quadrillions of stars, some of them like Betelgeux millions of millions of times as large—so that in comparison with a single star the Earth is like the dot of an *i* in a house, and in comparison with the whole of them, like a speck of dust on the Himalayas. And vaster still is space—so vast that light coming from the most distant stars at its usual rate of 186,000 miles a second takes more than a million million years to reach us, so

vast that all the quadrillion suns occupy an almost inappreciable fraction of its immensity. So tiny, so obscure is our planet amid myriads of great suns—so insignificant is it in the immensity of space! Well may we ask the Maker—if Maker we can conceive—"What is Man or the son of Man that thou shouldst be mindful of him?"

The origin of all these quadrillions of stars seems to have been enormous masses of cold luminous vapour—like clouds whirling in space—the so-called nebulæ, and each of the great nebula known to-day contains enough matter to make a thousand million suns. The size of the larger nebulæ almost passes conception. The Earth's path round the sun measures about six hundred million miles; but a sphere even of that huge girth would only be a millionth the size of the vast nebula of Orion—and *it* is only a shred of the greater nebula of the Milky Way from which it probably sprung. It is quite possible that in the beginning there was only one almost infinite rotating mist, and that out of it have come all the nebulæ and the suns and the planets that we know to-day.

What were the primal constituents of the nebulæ we do not know—possibly protons and electrons which are the fundamental units of atoms, possibly atoms, and if atoms, probably atoms larger, heavier, and more complex than any atoms known nowadays. For Jeans, one of the most brilliant intellects of the day, believes that the young suns are made chiefly of radio-active atoms, larger and more complex than the radio-active

atoms known to-day, and that the heat of the stars in their earlier stages is due to the behaviour of these atoms. This most interesting idea of a special kind of matter in the stars was first adumbrated by Newton, who, as long ago as 1692, suggested that stars must be made of a special kind of matter which he called " lucid " matter. Whatever the nebulæ are originally made of, their original texture is one of extreme tenuity. They and the young large stars are so thin and light in substance that a ten-pound weight of Betelgeux would more than fill the Albert Hall, and a ten-pound weight of the unformed part of the nebula of Orion would much more than fill all the railway trucks in the world.

Most nebulæ have a spiral structure with two arms. Any globular aggregation of promiscuously revolving particles tends to flatten down into a biconvex disc with particles all revolving in one direction, and as the central mass revolves more rapidly, the general circulation of the particles must come to have a spiral direction. But the *two* arms have to be explained, and most astrophysicists explain them as the result either of a tidal tug or of a collision. Arrhenius, for instance, maintained that the nebulæ are produced by collisions, that the shape depends on the character of the collision, and that what may be called a *half-ball-cannon* collision must result in a rotating spiral nebula with two arms, for, at the collision, matter will be ejected from both the celestial bodies at right angles to the relative directions of their motions, in two powerful torrents

situated in the plane in which the two bodies have approached each other.

That is Arrhenius' theory, but Chamberlin holds the tidal theory. When two bodies in space, of stellar or more than stellar size, pass within a certain distance of each other, the smaller is apt to be not only tidally deformed and pulled out by the other, but strained to such an extent that it bursts into fragments. The fragments of the elongated rotating mass will necessarily take on a whirling or spiral motion ; and the two tidal protuberances or elongations of the body, having also a rapid rotatory movement, will necessarily form a double spiral.

Once the spiral is formed, the gaseous matter in its arms will condense into knots under the influence of gravity and chemical laws—much as a cloud of steam condenses into drops—which are the stars ; and in many of the nebula such sun-knots are seen in the process of formation, so that we in time get clouds of stars.

In some such way our Solar System had its beginning in a nebula, and the Milky Way still records the position of its equatorial plane.

But the remarkable thing about our Solar System—a remarkable thing too rarely considered and realised—is that it had *two* beginnings—that it was, so to speak, made twice over, and that its double origin is almost unique in the Cosmos. For it is believed that in the first place a grèat sun condensed out of the great original nebula, and that in the second place another star rush-

ing past the great sun tore it tidally to pieces and converted into a little new nebula of its own, in whose warm arms condensed out all the planets:

> "Spindrift and spume of the vortiginous surge
> Of a sun-shattered sun."

What was exactly the nature of this new nebula we do not know, but quite possibly it consisted, like the nebulæ of Lockyer's and Chamberlin's meteoric hypotheses, of rocks and stones banging about in a fiery gaseous cloud, till finally

> "reeling from its gurge,
> Smelted and smoothened from the rough débris
> By the hot hands of Fire, the Thaumaturge,
> The Earth leapt free."

Formerly, as we know, Laplace's famous nebular hypothesis was the accepted explanation of the genesis of our Solar System, and it is so interesting in itself and so important historically that it may be outlined here. It held that a "firemist" once stretched from the position of the centre of our sun at least as far as the outermost planet of our System, and that, as the mist cooled and contracted, it threw off nebulous equatorial rings (such as are still seen in Saturn's Belt), and that these rings again collapsed and coalesced into globular masses, the planets.

According to a well-known law of mechanics—the law of conservation of moment of momentum—the spinning body must spin faster as it contracts, so that at intervals enough centrifugal force would be acquired to shed an equatorial ring. The first ring would be

thrown off where Neptune spins in its far-away orbit; the next would account for Uranus, the next for Saturn, and so on.

"It was a beautiful and plausible hypothesis—beautiful in its simplicity, plausible in its explanation, and to this day it has held captive the imagination of mankind. What bolder and braver vision could one have than the vision of this fiery mist rotating in space and flinging off from its fringes the molten world. What picture could be more fascinating than the picture of the birth of the world as a belt round the waist of the whirling sun."

But unfortunately the hypothesis is not mechanically sound. If the sun and planets were dispersed into space so as to fill an area bounded by Neptune's orbit, they would form a gas so thin that it could not possibly have coherence. Not rings, therefore, but nebulous wisps would be detached, and their detachment would be not intermittent but continuous, so that "Space would have been strewn with the debris of condensing nebulæ, and there would have resulted a vast cloud of cosmic dust, not a majestic array of revolving spheres."

Moreover, it can be proved by a law of physics—the law of areas—that when the firemist occupied the enormous sphere measured by Neptune's orbit, its rate of rotation must have been so slow that gravitation must have more than counterbalanced any centrifugal tendency, and, indeed, that gravitation must have counterbalanced centrifugal force even until such time

as the whole mass had shrunk to the size of the orbit of Mercury. Again, the several planets do not move at rates proportionate to the rate of rotation of the fire-mist at the time and place of their hypothetical origins, and this, if the hypothesis be true, they ought to do. For all these reasons Laplace's fascinating theory has been given up, and has been superseded by some tidal theory like the tidal theory of Jeans, and though the tidal theory be not quite so fascinating it gives quite as interesting a picture of the origin of our Solar System. The picture of a sun rushing past another sun and tearing it to pieces and converting it into a nebula certainly appeals to the imagination, but, further, it gives almost a unique origin to our System.

It might be thought that with some quadrillions of stars rushing about in space for millions and millions of years, collisions and tidal tugs would be frequent, and that therefore there would be multitudes of planetary systems like ours; but Jeans calculates that a collision or tidal tug happens only once every thousand million years—that in the thousand million stars surrounding our sun there are not more than ten thousand planetary systems, *i.e.* that only one sun in 100,000 has its retinue of planets. If a planetary system is made only every thousand million years, and if after millions of millions of years only one sun in 100,000 has such a system, then plainly our Earth and Sun have had a very uncommon history and have very few peers, and probably no duplicate, in the whole Cosmos.

And now before we go further, let us sum up briefly what we have discovered in regard to the past history of Man's home.

We have seen that the Earth is only one of countless millions of heavenly bodies, and that it and its sun are very tiny things compared with the sidereal giants of the cosmos. We have seen the amazing beginnings of our Solar System in an enormous luminous cloud made up of large complex radio-active atoms so thinly dispersed as to be lighter than any known gas. We have seen these scattered large complex atoms changed into smaller simpler ones and aggregated into hot knots —primal suns. We have seen one of the primal suns rent to pieces and changed into a spiral nebula by the tug of another passing star, and on one of the arms of the nebula we have seen appearing as new hot knots our sun and its planets.

Our sun, and the earth, and the planets began, then, as hot knots in a cloud of cold gas and stones produced by the disruption of a larger sun, and their ultimate origin was the large complex atoms in the original nebula. The original nebula, be it noted, had little or no heat: it was not a firemist; and all the heat in the Solar System, all the flames of Jupiter and the Sun, all the radiant energy of the molten metal of our planets, were produced simply by contraction under the action of gravity, by the radio-activity of the original atoms, by the falling together of electrons and protons, and by conversion into heat of the mechanical force of the tidal tug.

That is the picture modern astronomy gives us of the

origin of the material Cosmos and of the evolution of suns and planets.

That is a picture of the far astronomical past; now let us, with the aid of geology, look briefly at the progress of our planet from a knot of gas to a habitable world. Let us work forward from the astronomical past to the astronomical present.

At a certain stage, our planet was mainly a mass of large radio-active atoms in a gaseous state; but gradually these mysterious atoms broke down into simpler, more permanent atoms, which grew hot under the influence of radio-activity and gravitation, and in part formed molten chemical compounds and in part became hot vapours. The molten compounds hardened into solid ones, most of the heavier gases liquefied and came down as rain, and finally there was a crust half-molten and half-solid, and the globe acquired the semblance of a planet—a planet with seas of molten lava, and with clouds of vaporised iron—a planet torn by earthquake, tortured by volcanoes, scourged by a hail of meteoric rocks, and tugged by the sun into great tidal waves. At this stage it would be in darkness, lit only by the glow of molten lava and by intermittent lightning flashes, and through the darkness would hiss the heavy molten rain and would crash the falling rocks, and everywhere would be heard the groaning, griding, growling, crepitus of the cracking, rending crust. In my Ode "War" I endeavoured to give some idea of the Earth at that time after it had reeled out of the nebula, and as poetry can sometimes say

things better than prose perhaps I may be permitted to quote some passages :

" Around it, burned and boomed a plangent sea
That ever by the cruel knotted scourge
Of a wild crashing rain of crimson scree
Was whipped to plashing whirls of purple foam.
And ever lashing from its dædal dome
There hissed a heavy hail of falling stars
Whose flick upon the lava's filigree
Made rosy scars.

And ever from the coastal crust of slag
Slipped candent cliff and burning crag
Into the cauldron of the bubbling ore,
And steamed and wallowed in the red fiords
Like monstrous hordes
Of snorting dragons weltering in gore,
Stabbed in the loins with the long jagged swords
Of the livid lightning. Yea, and evermore
Came from volcano-throats the raucous roar
Of lava and of thunder; and the shore
Reverberated with the ponderous tide
As the sun rose in reckless wrath and tore
—Till the astounded stars heard the torn granite gride—
The bossy, slaggy moon from the Earth's riven side."

At this time, as the last lines I quoted indicate, the moon was born, and it is usually believed that it was torn out of the Earth's semi-molten crust by the tidal tug of the Sun. Darwin's son, Sir George Darwin, made a careful study of the mechanism of the great wrench, and his book on the subject is one of the most fascinating books in scientific literature.

When the Earth was in a soft, semi-molten condition, its crust, as it revolved, would be pulled out by the sun (which was nearer the Earth in these days), into a red billow running round the Earth as it rotated, and as

Sir George Darwin proved, at a certain stage the pull and the centrifugal tension in the crust would suffice to jerk out of it a great piece, or great pieces. The great piece or the coalesced great pieces, became the moon, and the deep wound in the Earth's crust—which is supposed to have been 27 miles deep—is believed by some to have become the depressed bed of the Pacific Ocean. At that time the Earth was spinning at a tremendous pace, six or twelve times as fast as now, and the moon revolved round it every three or four hours and was only ten or twenty thousand miles away, so that the tides in the semi-molten crust of the world must then have been very violent and convulsive. According to Sir George Darwin's calculations, the Earth bore the moon about fifty-six million years ago, when she was nearly two thousand millions of years old.

After that catastrophic birth the crust of the Earth gradually solidified. At first it had a temperature of over 1000° C., and any water then in existence must have been in the form of steam or vapour, but when it cooled down sufficiently the steam began to condense as hot water on the crust. In these days the surface of the Earth, like the surface of the moon, was thickly sprinkled with tremendous volcanoes, and probably the greater part of the world's water came from them in the shape of steam, and ran down the lava slopes to form the sea. It is noticeable that even yet the great oceans are ringed with volcanoes. It is quite possible, too, that the immense amount of lava vomited forth from the volcanoes undermined the Earth's crust, and

caused depressions which became the beds of some of the seas.

The violent hot rain, containing large quantities of acids and carbon dioxide from the volcanoes pouring down the steep lava slopes, must quickly have worn down the volcanoes and deposited much sediment in the early sea, and the world, when first made, before the sedimentary mountains rose out of the sea, was probably less mountainous than now, and consisted mainly of comparatively level great plains of lava.

Having, then, traced the origin of our planet in the flocculus of an enormous flimsy cloud composed of ultra-radio-active atoms, and having glimpsed its final fiery forging into a habitable world, let us glance at its present geologic structure, its planetary position, its central sun, and its solar relations.

The Earth has now attained to a placid rotund respectability, and, despite occasional seismic fractures, its crust, though probably only about fifty miles thick—about as thick in proportion to the whole globe as the rind of an apple in proportion to the apple—is safe from cataclysms. The volcanoes of the original crust have been worn down to their bases, and the ocean bed has alternately been luted with silt and raised as sedimentary mountains to the eagle skies, till now the present continents and seas seem to be pretty permanently settled. A staid, steady planet, Earth spins on its own axis while it circles the sun 93,000,000 miles away, and completes a yearly orbit of some 583,000,000 miles at the rate of 18 miles a second. With it revolves the other

members of the Solar System—Mercury, Mars, Venus, Jupiter, Uranus, Neptune, Pallas, Ceres. As we have already said, the Earth in comparison with most suns is a very tiny thing, and even compared with the other planets by no means a giant. It is larger than Mercury and Mars, but only a pigmy compared with Jupiter, Uranus, and Neptune.

The sun round which the planets revolve is a million times as large as the Earth, having a diameter of 865,000 miles as compared with the Earth's diameter of 8000 miles, but, as suns go, it is of very moderate size and luminosity.

Betelgeux could hold twenty-five millions of it, and Doradus emits three hundred thousand times as much light. An orb of spinning flaming gases it rushes through space towards the constellation of Hercules at the rate of 12 miles a second, and Earth and Earth's sisters as they revolve round it rush through space with it. Though it be small and dim compared with some other suns, it is prodigious in size compared with the Earth, and its radiant energy is terrible enough. The surface temperature is 6000° C., so that even there all its elements must be in a gaseous state; while in its interior the temperature, according to Jeans, reaches the incredible height of 50,000,000° C.—at which temperature a bit as big as a pea would scorch and shrivel up any one who ventured within a thousand miles of it, and would destroy an army if focused on it. It radiates into space from each square inch of its surface enough radiant energy to keep a 50-h.p. engine in continual

action, and the total heat it emits yearly equals the heat potential in 200,000000,000000,000000,000000 tons of coal, and would suffice to melt 40,000000,000000,000000,000000 tons of ice. All the coal produced in Great Britain in a year would not give more heat than is radiated annually from 50 yards square of the sun's surface. Now, according to the greatest modern authorities, the sun is five or ten million million years old, and all these æons it has been radiating heat and light and wasting away at the rate of at least 250 million tons a minute, so that it must have lost a great part of its mass; and though despite that loss it is still so huge that a million million years hence it will probably be much as now, and the Earth will still be revolving round it, yet in time the great luminary will have no more radiant energy left, and will become a cold, dead cinder like the moon, joining the millions and millions of dead suns that already cumber space.

One of the most amazing things about the suns and planets is their terrific speed through space and their gravitational relationships. Why is our little Solar System flashing along towards the Constellation of Hercules at the terrific rate of 18 miles a second? Why does it rush and what is its ultimate goal? Why do all the stars, even the dead stars, still move? Why do the stars and all aggregations of matter pull each other with a force directly proportional to their masses and inversely proportional to the square of their distance from each other? The physicists tell us that movement is as fundamental as rest, and that once a body is

started in movement it will continue till something stops it, and they tell us, too, that the moon swings round the Earth, and the Earth and Planets round the Sun under the influence of a pull of exactly the same nature as the pull that makes an apple fall to the ground. We have merely to know the mass of the mutually pulling bodies to know all about their movement, and with the same formulas we can calculate the rate at which an apple falls and the rate at which the moon falls round the Earth or the Earth round the Sun. But formulæ and comparisons and equivalences merely describe, they do not explain, and to me movement remains a mystery. I can grip a ball in my hand, jerk my arm forward and open my hand and the ball flies away through space, and the astronomers and physicists tell me that, if there were nothing to stop it, it would go on for ever and for ever to the utmost bounds of space. That may be, but what did I put into the ball so that, even separated from me by millions and millions of miles, it might go on moving as it never did before? What invisible thing do I put into a ball, I ask, to make it, apart from me, move for ever? And what invisible thing does the Earth send out to it to pull it back and stop it, and what invisible thing does the Earth send out to keep the moon falling round it? In each case there is something mysterious and something invisible, and I believe something that we may call spiritual. The something in me I call will and force is part and counterpart of the divine something that has flung the flaming suns into space, and when I give a ball eternal motion I am a conscious spirit

giving a tiny exemplification of the conscious moving Spirit of God, and every time I throw a ball I ought to realise the consequence spiritually of the motive power behind the revolving Earth and Stars—ought to realise that in me is something that is not in dead matter, something of the Spirit and Will of God.

Now, then, let us finally sum up the astronomical position of man—the position he has when we consider him as a cosmic product, and as a creature whose birthplace and home is among the stars. So regarded, we are cosmopolitans in a large sense of that word. We look back to our nativity in that marvellous luminous mist as if of God's breath condensing in the cold air of space. We see in that whirling nebula the large radio-active atoms breaking down into the permanent atoms of iron and hydrogen, and nitrogen and sulphur, and so on —see them crushed together till they become molten ore and flaming gas. We watch the volcanoes steaming and the steam condensing into rain and rivers and oceans. And all this ending in the habitable world in which we now live: all this blossoming into birds and beasts and men. Does not this astronomical view give us a larger vision of our environment and of ourselves? On this globe, knotted on a nebula and forged and moulded with such infinite ingenuity, we ride amid the stars, and swung by some mysterious force, and held by some mysterious band, circumnavigate the Sun and enjoy the changes of the seasons. Every twenty-four hours, our planet spins once round on its axis and gives us alternately Sun and Stars, Night and Day, while

twice a day "the gentle moon, that nothing doth but shine, lifts all the labouring surges of the world." We may be 640,000 miles from the moon and 93,000,000 miles from the Sun, but they lift our ships into harbour and ripen our cornfields. We may be countless light-years from the distant stars, but every star is needful for a rose, and light that shone millions of years ago—light from stars probably now dark and dead, gives beauty to our sky. From the last shreds of the Milky Way come tiny waves that hint that suns are still forming there, and we find in all the suns the same elements that we find upon Earth. In fact our home is part of the universe, inseparable from it, and our own life is cosmic in its immensity, and if in one sense we were born in iniquity and conceived in a mother's womb, in another larger sense we were conceived in a luminous nebula and born of lustral fire. Does not such a vast environment in time and space, such mysterious vital connections with the sidereal universe make us seem more than cunning casts in clay, more than putrescent dust on the weary satellite of a dying Sun? Does not the tremendous fiery preparation of our home, during millions and millions and millions of years, not suggest that there was a foreseeing Mind, and that we are here for a great purpose? Can indeed any man see the immensities of his relationships, and glimpse the infinity of the universe open to his eyes and his mind, without some sense of a "Being far more subtly interfused, Whose dwelling is the light of setting suns and the round ocean and the living air, and in the heart of man." The

Cosmos is more than a collection of lumps of matter, it is a living organism with the breath of God in its nostrils. There never was an atheist astronomer, "the undevout astronomer is mad," and if any man can stand on this planet reeling round the Sun—if any man can look at himself and the world in the light of cosmogony, and yet have no Sense of Mystery, no Sense of Wonder, no Sense of Deity, he is to be pitied, and

> "Great God, I'd rather be
> A pagan suckled on a creed outworn;
> So might I standing on this pleasant lea
> Have glimpses that might make me less forlorn.
> Have sight of Proteus rising from the sea,
> And hear old Triton blow his wreathèd horn."

We need only a little scientific imagination and a little scientific humility to see in scientific truth the full wonder and mystery of the world—to realise not only that the stellar universe is great; but that "the heavens declare the glory of the Lord and the firmament showeth forth His handiwork." Nietzsche may sneer—"Ihr habt den Weg vom Wurme zum Menschen gemacht und vieles ist in euch noch Wurm." We may answer—Yea, but it was a glorious worm—a glow-worm that crawled out of the crimson corolla of a star.

CHAPTER III

MAN SEEN THROUGH THE ULTRA-MICROSCOPE

"All knowledge begins and ends with wonder, but the first wonder is the child of ignorance and the second is the parent of adoration."
—COLERIDGE.

WE have gazed at man through the telescope of the astronomer, and have espied humanity a speck of dust spinning through space on the shard of a shattered sun, yet body and abode probably unique in the whole Cosmos.

Now let us go to the opposite extreme of Life and let us study the invisible through the ultra-microscope of scientific faith and scientific vision. Let us regard man amid the silent, invisible planetary systems of the "protons" and "electrons."

Before, however, we can interpret man in his relation to these invisibles, we shall have to do some heavy spade-work around the atom.

Firstly, what are atoms? Till the last decades of last century matter was believed to be built up of ultra-microscopical, indivisible, indestructible particles—atoms—the name itself, by its meaning, the "uncut-ables," indicating the belief.

Such a particulate conception of matter had long

been current. Democritus believed in such indestructible indivisible ultimates. Lucretius affirmed that "the principles of matter, the elements of the whole, are solid and eternal: no foreign action can change them. The atom is the smallest body in nature . . . it represents the last term of the division." Newton also believed in primitive particles "incomparably harder than any porous bodies compounded of them, even so very hard as never to break in pieces," "no ordinary power being able to divide what God Himself made in the first creation." But it was Dalton who elaborated it into a valuable working hypothesis by showing that the constant and definite proportions by weight in which certain simple chemical substances combined could be best explained by assuming that each consisted of indivisible ultimate particles of definite specific weight. This so-called atomic theory soon became the fundamental fulcrum of chemistry, and even towards the end of the last century the great Clerk Maxwell could declare: "But though in the course of ages catastrophes have occurred and may yet occur in the heavens—though ancient systems may be dissolved, and new systems evolved out of their ruins, the molecules out of which these systems are built—the foundation stones of the material universe—remains unbroken and unchanged."

It was a very natural and inevitable belief, for no violence could alter the character of the elements. They could be put in explosives, they could be bound in various combinations, but they always remained of the

same weight and showed the same characters according to their weight.

The atomic theory distinguished atoms by their weight—their "atomic weight"—the lightest atom, the atom of hydrogen, being taken as 1, and the others given proportionate numbers; thus carbon, twelve times as heavy as hydrogen, was said to have an atomic weight of 12; and nitrogen, fourteen times as heavy, was said to have an atomic weight of 14; and all the eighty odd atoms known were duly classified by their atomic number.

The theory was based on fact, and it is still held by all chemists and has still great practical value as a working hypothesis; but towards the end of the century, physicists proved the most sensational fact that the atom is itself made up of still smaller particles, and that under certain circumstances it actually breaks up. The history of the discovery of the complexity and destructibility of the atom is very interesting and may be outlined here.

Even before the particulate constitution of the atom had been discovered, Pflücker and Hittorf in 1865 noticed that certain elements, when subjected to great heat, showed spectra simpler than those shown by the same elements at ordinary temperatures, and that similar simple spectra were furnished by elements in sun and stars, and from the alteration in spectra they inferred that—as Faraday had fifty years previously suggested—the atoms had undergone a radical change and had acquired a new or radiant character. Prout and Lockyer went further, and expressed a belief—a quite shrewd belief—that the spectral change indicated

that the atoms not only had changed but had broken up, and had been reduced to the *materia prima* of which all atoms are built up; while in 1872 Herbert Spencer, with philosophic prescience, affirmed that "the properties of the different elements result from differences of arrangement, arising from the compounding and recompounding of ultimate homogeneous units." A few years later Sir William Crookes, who was experimenting on the effect of passing an electric current through a vacuum tube—a glass tube almost exhausted of air—noticed that minute particles darted across the vacuum with enormous velocity, and came to the conclusion that they must be a sort of dust of atoms—"the little indivisible particles with which good warrant are supposed to constitute the physical basis of the universe," and that in them we touched "the borderland where Matter and Force merge into each other."

All these thinkers were very near the truth, and very soon thereafter the truth was established.

In 1896 the famous French chemist, Henri Becquerel, when studying phosphorescence, accidentally discovered that salts of uranium emitted radiations or particles, very like the radiations or particles noticed by Crookes in the vacuum tube, and that the radiations or particles were able to pass through substances opaque to ordinary light. Next year the Curies discovered the far more radio-active element, radium, and its radio-activity was shown *to be due to the disruption of the atom—an explosive disruption that shot parts of the atom now* known as electrons and protons into space, and eventu-

ally transmuted the radium atom into the smaller, lighter atom known as lead. That was one of the most sensational and revolutionary discoveries ever made; it quite overthrew the old atomic doctrine of Lucretius, Democritus, Newton, Dalton, Clerk Maxwell, and soon led such great thinkers as Soddy, Rutherford, J. J. Thomson, Lodge, Moseley, to quite new and very amazing conceptions of the atom, of matter, of force, and of the universe.

It would be interesting to trace, step by step, the acute reasoning and the ingenious experiments that led to modern conceptions of the particulate atom, but here we must be content with a summary of the final conception.

Atoms, and of course matter made of atoms, are now believed to be essentially electrical in constitution. Every atom is a miniature planetary system with a nucleus or central sun in which there is positive electricity, or in which positive electricity at least preponderates, and round this central sun one or more satellites of negative electricity rushes. Both negative and positive electricity seem to occur in the form of minute indivisible particles, and the primitive negative particles have been called "electrons" and the primitive positive particles "protons."[1] Both are of about the same almost inconceivable minimitude—less than a millionth of a millionth of an inch—but the electron has

[1] Recent researches suggest that electrons and protons are analysable into waves, and that both are manifestations of the same basal energy.

no weight to speak of; practically all the weight is in the proton. Accordingly, the lighter atoms have fewer protons or particles of positive electricity in their nuclei and the heavier ones more. Thus the lighter atom, the atom of hydrogen, with atomic weight 1, has only one proton, while helium, with atomic weight 4, has four protons. All the compound nuclei—that is to say, all the nuclei save the nucleus of hydrogen—have a certain number of electrons incorporated in them which revolve round the central nucleus depends on how many *unneutralised* protons there are in the nucleus to hold and swing them. Hydrogen has only one proton, but that one proton is unneutralised and free, and so swings one electron; helium has four protons, and therefore might have been expected to sling and swing four electrons, but two of the protons are neutralised and put out of action by two electrons incorporated with them in the nucleus, and so there are only two free protons, and accordingly helium swings only two electrons. Now, the chemical characters of the atom have been shown to depend not on the heavy nucleus, but on the precise number of imponderable electrons swung by it. Atomic *weight*, therefore, is not of so much chemical importance as used to be thought; more important is "atomic *number*" or the number of electrons swinging and spinning around the atom.

Moseley, so lamentably killed by a Turkish bullet at Gallipoli, simplified the matter considerably by showing the very remarkable fact that all the ninety-two atoms now known can be put in a series and numbered

1, 2, 3, up to 92, in such a way that the numbers will represent the number of free *revolving* electrons each contains, and each atom will have only one electron more or less than its neighbour. Hydrogen, placed number 1, has one revolving electron; helium, as we have said, 2; lithium, 3; oxygen, eighth in the series, 8; uranium, ninety-second in the series, 92. The difference in the chemical character of each atom is just a difference of perhaps one infinitesmal satellite of negative electricity.

When there are many satellites they arrange themselves into several rings: uranium has six rings, and it has been shown that chemical affinities depend largely on the number of satellites in the outer ring.

Nothing could be more revolutionary than this revolutionary conception of the atom. Instead of being a passive indestructible thing, it has been shown to be a miniature solar system full of fierce movement and energy, and a solar system, too, that sometimes disrupts with cataclysmic violence. Instead of atoms being untransmutable, we find that some of them, like the atoms of radium, can be watched transmuting. And so far is the atom from being solid that the distance between electrons and between electrons and protons is as great in proportion to their size as the distance between the planets. Little specks of the atom are electric charges, and the rest is empty space. Compared with the atom the electrons are like midges in a cathedral. How infinitesimal, therefore, the electrons and protons must be we can imagine when we remember that a tiny

cell may contain—8,640,000,000,000,000,000 atoms, and that a single atom would have to be magnified millions of times before it could be seen.

Infinitesmal and invisible though electrons and protons are, the mind of man has watched them and measured them and timed them with amazing results. It has been calculated that the electrons measure less than a million millionth of an inch and that they flash round their little orbits at the rate of 1400 miles every second, making about 7,000,000,000 revolutions in a millionth of a second.

The revolving electrons are easily rubbed off—that is what happens when we make electricity by friction—but so long as the bereaved proton remains in the nucleus it will soon get a new stone for its sling and restore and maintain the original character of the atom. If, however, as sometimes happens in radio-active atoms, both the proton and its electron are ejected, the atom permanently loses a revolving electron and becomes another element with other chemical properties.

The amount of energy represented in the electric constitution of the whirling electric systems is prodigious. The energy of our bodies and most of the energy (apart from gravitation) in action in the world is of inter-atomic or inter-molecular, *i.e.* of chemical, origin; but the energy confined and locked up within the atom is millions of times greater than any energy in action to-day. The energy of our bodies is supplied by the explosives in our food—we shall go more fully into that matter later—and we are proud of our muscular

power, but that inter-atomic or inter-molecular energy of the muscles is as nothing compared with their intra-atomic energy. Every cell in our bodies is, as it were, packed with dynamite or lyddite, and we are like torpedoes firing pop-guns.

Let us give a few picturesque figures to illustrate the intra-atomic energy. Le Bon has calculated that there is more than enough intra-atomic energy in a copper farthing piece to drive an ordinary goods train on a level track, more than four and a half times round the equator of the Earth. Sir J. J. Thomson has estimated that a few grains' weight of hydrogen contains enough energy to raise a million tons to a height of more than three hundred feet. When an atom like radium explodes the intra-atomic energy is set free, and Professor R. K. Duncan has calculated that the heat evolved by radium emanation is "over three million five hundred thousand times greater than that let loose by any known chemical reaction."

Energy is largely a question of velocity: the head of a pin spinning fast enough would have a mechanical power equal to some thousands of locomotives, and we have already pointed out the speed of the electrons revolving in the atom.

Even more startling than these startling facts we have already mentioned is the amazing, yet truthful, heresy to which they have given birth, the boldest heresy in the whole history of science since Copernicus declared that the Earth went round the Sun. There was no orthodox belief in science that seemed more secure

than the belief that matter was indestructible. Science, as we have already said, taught and demonstrated with delicate balances that matter was never destroyed—that whatever processes we applied to it, it never diminished in mass. We could put atoms into any compounds, they still came out unaltered in weight. We could convert a candle into water and gases, the water and gases had exactly the same weight as the original candle. Even the breaking up of the atom did not necessarily affect that fundamental article of the scientific creed, for presumably the particles of the atom would together just equal in weight the intact atom. The following statement, made towards the end of the last century by Professors Tait and Stewart, stated the universal opinion of science at that time. ' Do with it what we please," they wrote, " we cannot make our senses indicate to us an increase or diminution in a given quantity of what we call matter. We find it so far amenable to our control that we can alter the arrangement, form, density, state of aggregation, temperature, etc.; nay, by so approximating it to other matter as to produce a chemical combination, we may entirely transform its appearance and properties—*all but one*, mass or quantity is completely beyond our control. Measure it by what process we please, by the 'muscular sense,' by weight, anything; there it is, altogether independent of us, laughing our efforts to scorn."

Yet even this mighty confident dogma of science was overthrown by the electrons, and to-day science believes

that matter is constantly destroyed by being turned into radiant energy. To understand this conversion we must understand something about the ether, something about radiation, and something about the relationship of the ether to radiation.

In discussing the ether we must face the fact that it is an hypothesis ; and an hypothesis for which Einstein *n'a pas besoin.* But Einstein's interpretation of matter and energy space is mathematical : it is true only from the mathematical standpoint, and to give up the hypothesis of ether in physics because Einstein does not need it in mathematics is like giving up the hypothesis of electrons because Euclid does not need it in his propositions. What I specially wish to urge is that truth is partial and many-sided—that phenomena can be regarded from many aspects, and that though the aspects taken singly may seem contradictory they may usually be reconciled in a larger synthesis and together give us a Vision of the Truth which is in God.

As an hypothesis in physics the hypothesis of the ether is just as valuable as the hypothesis of gravitation—also abolished by Einstein—is valuable in gunnery in determining the parabolic path of a projectile, and the contradictions of the theory are no more damning than the contrariness of parallel lines which insist in meeting in infinity. It is a splendid working hypothesis that serves to unify the universe, especially the phenomena of light and electricity. The acute-minded Greek philosophers held that there must be something material between the eye and distant bodies to bring them into

some kind of an effective relationship with each other. Empedocles, Plato, and Hipparchus, for instance, supposed that the sun and visible bodies projected some kind of rays that met and touched another ray projected from the eye—just like stretched-out hands and arms. Epicurus and Lucretius supposed that something extended from the eye and touched bodies as we touch objects with a stick. The Pythagoreans maintained that visible bodies emitted streams of particles which bombarded the eye, while Aristotle, presaging the modern theory of ether, held that light was an act or energy (*energeia*) of a transparent medium between the eye and the lit-up object.

With the Greek philosophers the great English philosophers Newton and Hooke agreed, and Newton declared that the idea "that one body may act upon another at a distance through a vacuum without the mediation of anything else by and through which their action may be conveyed from one to another, is so great an absurdity that I believe no man who has in philosophic matters a competent faculty of thinking can ever fall into it."

Philosophically I think that the position of the Greeks and of Newton and Hooke might be contested. When Carlyle was asked to agree that a body cannot act where it is not, he answered, "With all my heart, but pray where is it?" And, in accordance with Leibnitz's axiom, "quod non agit non existit," it might be inversely argued that a body is where it acts and extends as far as its action extends.

Anyhow, whether the belief be contestable or not, Newton and Hooke believed that something must fill space and act as a medium between distant bodies, and they developed the hypothesis of an undulating medium —a medium so pervasive that it fills space and so evasive that Lord Salisbury once said that it was nothing more than the nominative case of the verb to undulate.

An undulating capacity was the main character given in the first place to the hypothetical medium, for light travelled across space in a manner that could best be explained by supposing that it came in tiny waves travelling at a certain rate through an undulating something, and the hypothesis of an æther and the hypothesis of light waves are mutually inter-dependent. Since light came from distant stars on the very confines of space, the medium had to be postulated as not only undulating but ubiquitous. "The vast planetary and interstellar regions," said Clerk Maxwell, "will no longer be regarded as waste places in the universe which the Creator has not seen fit to fill with the symbols of the manifold order of His Kingdom; we shall find them to be already full of this wonderful medium, so full that no human power can remove it from the smallest portion of space or produce the lightest flaw in its infinite continuity. It extends unbroken from star to star, and when a molecule of hydrogen vibrates in the Dog Star the medium receives the impulse of these vibrations and, after carrying them in its immense bosom for several years, delivers them in due course

and regular order and full tale into the spectroscope of Mrs. Huggins at Tulse Hill."

Now what kind of medium must it be to be able to transmit undulations at a rate of 186,000 a second, able to permeate all matter and yet allowing suns and planets to rush through it without friction. Certainly it cannot be liquid, nor solid, nor gaseous. Clerk Maxwell thought it must consist of tiny rapidly rotating spheres. Dr. Larmer thinks it must have a "structure of tangled or interlaced vortex filaments"—whatever they may be; Professor Eddington considers it merely a symbol, and other physicists have advanced other theories. Whatever it is, it certainly has amazing properties. Sir Oliver Lodge, who has studied it from a standpoint of physics for a long lifetime, finds that it has prodigious density and elasticity. It is a million million times denser than water; its pressure is millions of tons to the square foot, and its elasticity must be expressed by a million million million. So enormous is the intrinsic energy of its constitution that every cubic millimetre of it (a millimetre is $\frac{1}{25}$th of an inch) possesses a mass of 1000 tons (*i.e.*, it would be as difficult to start this tiny cube of it in motion as to move 1000 tons) and energy equivalent to the output of a million-horse-power station for 40,000,000 years. Let me quote Sir Oliver Lodge's own words: "Hidden away in its constitution is a fundamental and absolute speed, a speed not of locomotion but of internal circulation. What it is that is thus whirling we do not know: without the whirl we can have no conception of it. The

whirl and the fundamental something together make up the Ether. And we have no power of detaching the one from the other, hardly even in thought. . . . It is the seat of prodigious energies—energies beyond anything as yet accessible to man. All we know of energy is but the faint trace or shadow or overflow of its mighty being."

That, then, according to Sir Oliver Lodge, is the medium that transmits light, and the undulations of light are undulations of these mysterious Niagara whirls. To account for the transmission of light we have been obliged to postulate this amazing mysterious medium, and are reminded of the saying that if there be not a God it would be necessary to invent Him.

It is believed now that the atomic planetary Systems we have just described are simply ether differentiated in some way from the rest of the ether—simply a special manifestation of ether energy, and, as we have already pointed out, far the greater part of matter still remains in the form of ether of space. Regarded thus, matter would seem to be made of such energy stuff as space is made of, and radiations of light and energy through space would seem to be a transformation and translation in wave form of altered energy contained in matter. All radiation of light and heat and electricity through space can be shown to be due to energy transmitted from the electrons to and through the ether.

And now to come back to the question of the annihilation of matter. We have stated that the electrons are electric charges in motion. Now, an electric charge in

motion acquires mass and inertia according to its speed, as any one can prove for himself by turning the charged plates of a static electricity machine—the quicker one turns them the more inertia they have and the harder they are to turn round. We may be said to be creating matter when we turn the charged plates. It is a motion that converts the electrons into matter, and when the motion is suddenly stopped or retarded the matter made by the motion is converted into an electro-magnetic wave or radiation which ripples through the ether with an energy equivalent to the energy of motion of which the electron has been deprived. Thus, when an electron rushes across a vacuum tube, and is stopped by the glass, its energy of motion and the mass that motion has given it are changed into X-ray radiations which are more or less energetic and penetrating according to the speed at which the electron has been rushing along in the vacuum tube. All radiation is at the expense of matter or mass.

Most light radiations from solid substances like carbon are due simply to a disorderly clashing and jostling of heated electrons. The electrons rush about, bang into each other, and losing motion lose mass and change into radiant electro-magnetic energy, which undulates along through the ether as heat or light waves. If we heat a solid slightly, the jostling of the heat-excited electrons will have enough energy to produce only slow heat waves; if we heat it more, the electrons will rush about more actively, and when stopped by collisions will turn into faster red light waves; and if we heat it

still more, we shall get still shorter and quicker green waves; and if we heat it still more, various collisions of all kinds and degrees will produce radiations giving us the sensation of white but containing all the colours in a rainbow.

The details are a little difficult to understand, but the main big principle is just that electrons in motion produce what we call mass or matter, but that if this motion be retarded or stopped some or all of the matter so produced disappears, and in its place appear the electro-magnetic waves in the ether which we call radiation—radiant light and heat, etc. When an electron rushes into a proton both disappear, transmuted into enormous quantities of radiant energy.

If a man having charged his garments with negative electricity could rush through space fast enough and suddenly stop, the sudden stoppage would clothe him in a garment of red or green light according to his speed, and the electrons would be no more. But as he ran he would find it increasingly difficult to run, for the speed would increase the mass of electrons and the increasing mass would resist movement, just as the charges on the revolving discs of static machines acquire more mass and resist motion.

The relationship between the motion of atoms and light waves has been worked out in the most astonishing way in the case of the light coming from atoms in glowing vapours. Here the waves are not, as in the case of glowing solids, caused by collisions of free electrons, but by a jerkiness of the movement of the electrons

while still revolving in their orbits, and the nature of the light as shown by the spectroscope depends on the electrotonic constitution of the atom and really reveal- that constitution—a principle on which the spectroscope identification of glowing gas depends.

For long the relationship between the light given off from glowing atoms and the atom's constitution was a mystery, and somebody said that it was as impossible to discover the constitution of an atom from its light as to discover the constitution of a grand piano from the noise it makes when thrown downstairs. But nevertheless a young Danish genius, Niels Bohr—the Newton of the atom—solved the problem some years ago, and gave us new insight into the infinitesmal world of the invisible. By dint of acute reasoning, Niels Bohr showed that the electrons revolving round the nucleus have certain definite and alternative orbits in which, according to the energy in them at the time of revolution, they revolve, and that the light emitted by an atom in a glowing state is due to the pull-up and jerk that the electron experiences as it jumps from one orbit to another. The electrons require more energy to move round in the larger orbits, and if an atom is given more energy by heat its electrons will move in the alternative outer orbit. If now it falls from an outer to an inner orbit requiring less energy of motion its surplus energy of motion is thrown off as electro-magnetic waves of light. It is simply a special case of the conversion of energy of motion and mass into waves of ether. The exact waves given off depend on the extent of the drop,

and the amount of excess energy of motion discharged as radiation. Thus an electron of hydrogen dropping from orbit 3 to orbit 2 will produce waves of red light, while an electron dropping—a longer drop—from orbit 4 to orbit 2 will produce the shorter and more energetic waves of green light, while electrons dropping away down into the innermost orbit will produce the still shorter and more energetic waves of X-rays.

Has there been in the history of the human mind any intellectual achievement so wonderful as this achievement in the astronomy of the invisible? To me it seems perfectly astounding! The electron is less than a millionth of a millionth of an inch in size; its average orbit has a radius of less than two hundredth millionths of an inch; round in this orbit it revolves 7,000,000,000 times in a millionth of a second at the rate of 1400 miles a second, and yet the mind of man has been able to show *precisely* the different orbits in which the electrons revolve, and has been able to prove that they jump about between them and give off just the right amount of energy and lose the right amount of mass to produce the various waves of light. We collect the light from a star millions and millions of miles away—perhaps light from a star that was annihilated millions of years ago—and if we see certain coloured lines in certain places in the spectrum we know beyond the shadow of a doubt that millions of years ago, millions of miles away, an invisible electron fell an infinitesmal distance from one infinitesmal orbit to another. The wonder of it—the

infinite accuracy of nature and the almost infinite achievement of the human mind take the breath away! Could anything be more wonderful than the atom unless the mind whose atoms interpret it? And all this energy, all this precision of atomic and of mental energy came from the ether, and yet there are people who do not feel compelled to postulate a God!

So far I have assumed a certain amount of knowledge with regard to waves of radiation passing through the ether; but the waves themselves are of immense intellectual and imaginative interest, and a few words about them may be said here.

Waves of radiation in the ether vary from mile-long waves such as are used in wireless, vibrating a few thousand times a second, to gamma rays and cosmic rays of very much less than a millionth of an inch, vibrating trillions or quadrillions times a second. Between the longest and the shortest come the violet indigo blue green orange yellow red waves of visible light. Of these the red, which are next door to the invisible infra-red waves of heat, are the longest, measuring about $\frac{1}{40000}$th of an inch, and the violet, which are next door to the invisible ultra-violet, are the shortest, measuring $\frac{1}{60000}$th of an inch. Only the waves between these lengths affect the eye, some of the others we know as heat and recognise as electric waves, the invisible ultra-violet, and some like X-rays and cosmic rays we can detect by their chemical or electrical effects. In the life of man and other living things they play various parts. Without radiant heat from the sun

to warm us and to sustain plant life, we should be frozen or starved; under some circumstances some of the ultra-violet rays are beneficial in rickets, and it is quite possible that the cosmic rays may have some vital siginficance.

One of the most extraordinary things about the radiations is that whether visible or invisible, long or short, thermic or electric, they are all magneto-electric waves going at exactly the same pace—186,000 miles a second—through the ether. Like runners with short legs the shortest waves of radiation must vibrate at a tremendous rate—sometimes hundreds of trillions every second—to maintain such a terrific pace; but whether wave of red light or violet light or dark heat or electricity they all run abreast through the ether like well-drilled soldiers dressed in various uniforms, yet always "dressed in line." Light takes $\frac{1}{14}$th of a second to travel from London to the Antipodes, and radio waves take exactly the same time. Light from far stars that has taken 140 million years to reach us, and waves from our Sun all go at the same pace, and no ray once started varies its stride, long or short, through the ether. We boast sometimes of accurate chronometers, but what scientific instrument can rival such infinite accuracy? Verily the ether that can carry a wave unchanged in stride and pace for millions of years over countless millions miles of space must be a miraculous medium.

That is a very brief account—I trust I have made most of it intelligible—of the modern electrotonic

theory of the atom and of matter. It makes demands on our scientific faith and scientific imagination such as no other theory—not even the theory of organic evolution—has ever made, and it offers a magnificent conception of matter that is almost inconceivable. Where our naked eyes see suns, and stars, and stones, and seas, and roses, and birds, and beasts, science knows neither light, nor beauty, nor solidity, nor colour, merely incredible agglomeration of miniature solar systems all made of exactly the same two constituents, protons and electrons—charges of positive and negative electricity. Where we see placid blue skies and stagnant pools and immutable mountain ranges, science sees turbulence—myriads, and myriads, and myriads of rushing satellites and shooting meteors.

> "We vaunt the new world we have found,
> Yet in that world the roses fade;
> There is nor scent, nor light, nor sound,
> In the star-clusters we have made;
> We have but loosened and unbound
> The broideries of beauty's braid."

We have been accustomed for long to realise that atoms throbbed and waltzed even in solids—that has been more or less conceivable—but these tiny systems with electrons rushing at the rate of 1400 miles a second and making 7,000,000,000 revolutions in a second baffle and bewilder.

What is a white rose to the eye of Physics? At best a Milky Way or a white nebular cloud. What is the difference between a bubble and a diamond and a golden nugget? Merely the difference between a few invisible

satellites—between atoms with a few more, and atoms with a few less infinitesmal and invisible electric charges.

Even more nihilistic and revolutionary is the electrotonic theory, for it seems to abolish matter altogether, or almost altogether, and to make mechanical ghosts of us, while we are still alive—mechanical ghosts among spectral machinery—little thin dust clouds in infinite space. For not only are our blood corpuscles, and our brain cells, and our eyes, and our hard bones and our soft muscles nothing but such whirling systems—that is extraordinary enough and incredible enough in all conscience—but we are mostly empty space, or what we call empty space, for the electrons and protons are as few in proportion to the apparent volume of our bodies as the stars are few in proportion to space. I, who stand before you now clothed in flesh and cloth—I, who look fairly solid and continuous, am really a hollow ghost, for though, according to physics, I consist of quadrillions, and quadrillions, and quadrillions of invisible infinitesmal particles, yet they are so small themselves that I am actually emptier than a vacuum tube, and if some terrible grip were to squeeze these particles together, as they have been squeezed together in some dead suns such as Maaneu's star, they would not fill a split pea. There is a conjuring feat for you if you like —the kind of conjuring feat that I personally think only a God of Miracles can perform—a living man—brain, and eyes, and heart, and liver, and limbs, and all they imply, made simply by putting in motion certain

particles that in bulk would not fill a pea. That is a conjuring feat, and I have still the most incredible, inconceivable part of it to mention. How much do you think the half-pea-full of electric materiality would weigh? It would weigh about 160 lb., and if you managed to lift it in your hand, you could not throw it more than a few inches, and if you let it fall it would go through the floor.

That is what I am, that is what matter is—a hundred tons of the only stuff matter contains could be packed into a pocket-book—the rest is space and "such stuff as dreams are made of."

Every mountain, every cloud, every radiant sun, every flower, every animal is made up of these amazing whirling systems of electricity. Why their orbits should be bounded to keep within the periphery of a star we might explain by gravitation, but how explain their bounds within the skin of a man or a petal of a lily, and their differentiation—or what seems to us differentiation—into cells and fibres? We can understand in some measure how atoms and molecules as they used to be pictured—hard, solid particles—could be moulded into shapes and forms of feathers, and blood-cells, and eyes, and lips, but constellations!—that is beyond us to comprehend, we flounder in the deeps of infinity.

This discovery that we and the world can be analysed into vast voids or, if you will, plenums of ether sprinkled with myriads of miniature planetary systems, is a tremendous revelation; but still more tremendous it

seems to me is the revelation that even the protons and electrons can be annihilated.

The discovery that if the movement of the whirling electric charges that constitute matter be suddenly arrested they change from matter into radiations of light, etc., in my estimation is one of the most amazing discoveries science ever made. As the discovery of radio-activity overthrew the dogma of the indivisibility of the atom, so this discovery of the relationship between radiation and the mass of the atom overthrew the still firmer dogma of the indestructibility of matter, and showed that matter is no more indestructible than a sunbeam—in fact *sunbeams are the shining ghosts of defunct matter*. In our sun to-day we have not only oxidation going on, but we have matter melting away into radiation and undergoing actual annihilation, and we have also, according to J. H. Jeans, electrons and protons falling into each other's arms, and vanishing into radiation. Every day the sun is losing 360,000 tons of its mass, all converted into radiation—into waves in the ether; and already it has lost in this way most of its substance. The only large suns are young ones: the old suns have mostly died away into ether waves. The amount of heat given out when each atom is annihilated must, of course, be equivalent to its whole tremendous internal energy, and is very great. Jeans calculates that a single drop of oil transmuted in this way into radiant waves would produce enough energy to drive the *Mauretania* across the Atlantic.

Physicists can prove that the annihilation of a single

electron must produce a radiation of waves of shorter wave-length even than X-rays, and of much greater penetrating power, and it is probable that the very penetrating *cosmic* rays—rays recently discovered, corresponding to sixty million volts and able to penetrate 5 yards of lead—are produced by the annihilation of electrons in the Milky Way. These cosmic rays seem to be the most plentiful rays in space: they shoot right through our bodies, constantly breaking up millions of our bodily atoms every second. Whether they are angels of health or goblins damned we do not know, but they at least inform us that matter in great quantities is breaking down, and it surely gives us a deeper sense of the wide and mysterious relationship of life to know that the annihilation of some invisible infinitesmal charges of electricity sent waves millions and millions of years ago across millions and millions of miles, and that to-day these waves shoot through us and break up millions of the atoms of our body. How far off in eternity, how far off in infinity, may be the causes of some of these things that happen to us in 1930 when the radiant shards of a star that was annihilated millions of years ago go through our heart to-day!

This conversion of matter into waves passing through the ether whirls seems to be going on everywhere. "Observation and theory both indicate that the universe is melting away into radiation," and as Jeans picturesquely points out, "The radiation of ten thousand dead universes may even now, for aught we know, be wandering round space; nothing less than the radia-

tion of hundreds of thousands would be susceptible of scientific measurement, thus we cannot tell how many universes may have perished into radiation and be wandering in this ghostly form around space." Yet what is all the mighty energy of all the atoms of the universe compared with the energy of the squirming ether. It is as the energy of a firefly to the energy of millions of suns, and when all the universe has melted into the ether it will be mass to mass like a grain of sugar melting into the Atlantic. Surely such thoughts give us some realisation not only of the minimisistude of our bodies but of the infinitude of our minds.

Here the question naturally rises: If matter dies away into radiation, may not cumulative radiation in turn become matter again? Sir J. J. Jeans, who probably knows more about it than any other living man, answers that the transformation of matter into radiation is a one-way, irreversible process. "Matter," he says, "can change into radiation, but under present conditions radiation can never change back into matter. . . . The universe is like a clock which is running down, a clock which, so far as science knows, no one ever winds up, which cannot wind itself up, and so must stop in time. It is at present a partially wound-up clock which must in some time in the past have been wound up in some manner unknown to us. By studying the mechanism of the clock, and noting the length of spring which is still coiled up and the length already uncoiled, we can estimate the length of time since it was wound up, but we can obtain no evidence as to

the way in which it was originally wound up and set going."[1] But as Sir J. J. Jeans also points out, a universe which runs down like a wound-up clock cannot be a fortuitous concourse of atoms and radiation. "Everything," he declares, "points with overwhelming force to a definite event, or series of events, of creation at some time or other not infinitely remote. The universe cannot have originated by chance out of its present ingredients, and neither can it always have been the same as now." That is the verdict of one of the greatest minds England has ever produced.

The Physics of to-day, therefore, conducts into a whirling universe of mysterious machinery wound up but running down. As seen by Physics the world is not a world of beauty and colour; it is a world of invisibilities, yet a world of such exquisite perfection, of such prodigious power, of such mighty mystery that, as rational men of science, we are bound to infer that it was wound up by an infinite Wisdom and an omnipotent Will—that the Hand that made the amazing atoms and that crushed the cold luminous nebula into flaming suns was the Hand of a God.

[1] The great American physicist, Millikan, believes that the cosmic rays indicate the creation of atoms in cold interstellar space, and that even as atoms are converted into radiation, so radiation is converted into atoms.

CHAPTER IV

MAN AND LIFE

" Is it easier to believe in an Eternal Bathybius than an Eternal Creator ? An Eternal Slime than an Eternal Intelligence ? "—CARDINAL MANNING.

" Ce ne sont pas les cellules qui font les organismes mais ceux-ci qui font leur cellules."—Y. DELAGE.

" And without Him was not anything made that was made."

" Scientific thought is compelled to accept the idea of a Creative Power."—KELVIN.

IN the first chapter we traced the *materies* of the Solar System to a cold luminous mist of ultra-radio-active atoms and showed how the Earth's cosmic history and sidereal relations bring Man into touch and tune with almost infinite immensities.

In the second chapter we showed the tremendous energy in the atoms, and the relationship between matter and radiation. But neither in the nebulæ nor in the suns nor in the whirling planetary systems of the atom have we seen any signs of the energies of life or detected any reason why life should blossom on the planet.

How, then, did Man and other living things ever come to be upon the big basalt ball spinning through space ? With little hesitation Science answers that Man and all living things were made of dust.

Animals and plants are all composed of a chemical substance called protoplasm, and this substance is

made of atoms of carbon, hydrogen, oxygen, nitrogen, sulphur, calcium, phosphorus, iron, sodium, potassium, and water, all of which remarkably enough were ready to hand in the primal crust of the Earth. Indeed, all the metallurgical processes in the hot crust seem almost as if they had been a prescient preparation for the making of protoplasm.

The mighty prehistoric volcanoes snorted out steam mixed with carbon dioxide, and the steam mixed with CO_2 condensed into acid water. The acid water running down the volcanoes and corroding the igneous rocks, made sea-brine and sea-mud which contained sodium, potassium, calcium, sulphur, phosphorus, while oxygen and hydrogen were formed by the thermal decomposition of water in the hot crust, and nitrogen was added as a by-product. In this manner all the necessary atoms were assembled ready to be made into protoplasm—into bacteria and lowly forms of life. It seems to me a remarkable thing that they were all there ready to hand, yet there they were.

But to assemble is one thing and to compound another. How, we ask, were the assembled atoms in the first instance compounded? Science does not know: science has never succeeded in compounding them into living tissues; the only living things science knows are living things produced by living parents, and science has never seen them compounded; but nevertheless science, courageously, perhaps recklessly, usually affirms that the organic grew by ordinary chemical processes out of the inorganic, and that "living organisms are chemical

products of warm mud and atmospheric gases,"—it believes that when the crust of the cooling and sterile earth attained a suitable temperature, atoms of carbon, hydrogen, oxygen, nitrogen, etc., combined, under the ordinary laws of chemical affinity, to form gigantic molecules of the vital substance "protoplasm"—a self-generating, reproductive, carbonaceous jelly, and that "the complicated chemical constituents of protoplasm reacting *inter se*, and with environment, gave rise to assimilation, metabolism, reproduction, movement, and the other functions called vital by which we define living things." According to science, too, the first little speck of protoplasm was chemically constituted in such a way that it not merely multiplied by division and budding, but coincidently varied and mutated, so that eventually, by the selection of variations and mutations, various species of unicellular organisms came into being. In time were evolved variant cells whose buds did not break off, but—arranged in certain definite orientation and form—maintained chemical and structural connections with each other and became lowly multicellular organisms; and finally the germ cells of these lowly multicellular organisms evolved, still by a process of variation and selection, into the wonderful ovum of Man.

Thus, according to science, an adventitious muddle of atoms in a muddy puddle—atoms luckily contributed from all quarters—grew by processes of consecutive chemical combinations into the human ovum. So, too, according to science, there may be to-day in any muddy

puddle elements able, simply by chemical affinities, to grow into a man! We who have seen chemists unable to do much more with dead atoms than to make a dye, or an explosive, or a lump of sugar, may find it difficult to believe that chemical affinities alone could lead to compounding of living organisms. But still there is a plausible case to be made out for chemical continuity between the inorganic and the organic processes of life, and it is found to be extremely difficult to draw a line between the living and the dead, and from some points of view it may be almost impossible.

Historically, we find plenty evidence of the difficulty of insulating live and dead matter. Early peoples, indeed, did give life and even deity to natural objects now considered dead. Thor and Ceres and Neptune, and Astarte and Ra, were all personifications of natural phenomena. In the days of the Greek philosophers a tendency to vitalise the inorganic persisted, and we find that Plato conceived a World Soul that moulded matter into archetypal forms; that Anaxagoras gave his atoms Love and Hate; and that the atoms of Lucretius were endowed with *concilium,* and a sort of embryonic *free-will.* We find, too, that Zeno and Strato deemed the world a living being; that Aristotle considered the stars to be passionless beings; and that Anaxagoras was cast into prison for asserting that the sun and moon were made of earth and stone. Even in the Middle Ages the distinction now made between living creatures and inorganic matter was not clearly drawn. In the twelfth century we find Moses Maemonides

writing: "Know that this universe in its entirety is nothing else but one individual being . . . just as Said is one individual, consisting of various solid substances such as flesh, bones, sinews, various humours, various spiritual elements." In the sixteenth century Giordano Bruno, the brave monk who was burned alive, felt it necessary to conceive of matter as made of monads possessing not only material but also spiritual characteristics. Van Helmont, in the seventeenth century, preached the same doctrine; while Leibnitz considered that there was "nothing sterile and nothing dead in the universe," that "each portion of matter may be conceived as a garden full of plants and as a pond full of fishes," and that there were monads of matter with "appetition," "petites perceptions," and "apperceptions." Even in the last century Haeckel gave the atoms sensation and will; and W. K. Clifford considered them bits of mind-stuff, and thought that there was a faint beginning of Sentience in the elements. And still more recently Professor William Keith Brooks, of the Johns Hopkins University, has declared that it is no less nonsense to assert that stones are unconscious than to assert they are conscious. So that science has an unbroken line of historical tradition behind it, and can teach abiogenesis and necromancy without doing any violence to its former doctrines or to popular preconceptions.

Further, the analytic methods of modern science, so far from making it easier to define the line between the dead and the living, have made it much more difficult,

for they have shown not only that the molecules, even of dead matter, are in a state of amazing activity, but that they possess a sensitivity to environment resembling the sensitivity of living plants and animals. To-day, Herbert Spencer's famous definition of Life as "the continuous adjustment of internal relations to external relations" will not do at all, for molecules of dead matter do constantly react and adjust themselves to environmental stimuli, such as heat and electricity. We can see and measure the movements of the molecules of alcohol, and mercury, and gases, under the stimuli of heat and cold, and we can often see and measure the movements in a solid. So sensitive and responsive indeed are metals to heat that their electrical conductivity is altered by a variation in temperature of less than one millionth of a degree. And metals are sensitive not only to changes of temperature, but also to electricity and to light. If a steel wire be touched with the tip of a finger, its molecules are altered by an electric current. The faintest ray of light falling upon a delicate platinum wire known as a "bolometer" produces a change in the molecular structure of the wire. Not only so, but metals seem to be poisoned or fatigued, or depressed or stimulated, just like living organisms. It has been shown that in a sense sodium carbonate stimulates and that potassium bromide depresses certain metals—that the electrical excitability of metals may be diminished by such poisons as veratrine, and abolished by such poisons as oxalic acid. It has been even shown that fatigue in metals runs the

same course as fatigue in living tissues. Extraordinary thing indeed that metals can be poisoned and fatigued, and depressed and stimulated!

Among the most characteristic of living products are enzymes or ferments, by which most of the functions of living organisms appear to be carried out. "It seems well established," writes Professor Bourne, "that the activities of cells are, if not wholly, at all events largely, the result of the actions of the various kinds of enzymes held in combination by their living protoplasm." These ferments or enzymes are albuminous substances which have the power of chemically changing other substances without themselves undergoing any apparent change. The ferment "rennin," for instance, can curdle almost a million times its weight of milk, the ferment "pepsin" can alter half a million times its weight of fibrine, and a little of the ferment "amylopsin" can break up a large quantity of starch. But even these vital ferments can be emulated by colloid metals—*i.e.* by metals broken up into particles of a certain minute size. Thus colloid platinum decomposes oxygenated water (as do certain ferments of the blood) and transforms alcohol into acetic acid (as do the ferments of the *Mycodermi aceti*), while colloidal iridium acts like the ferments of certain bacteria and decomposes formate of lime into carbonate of lime, carbonic acid, and hydrogen. Extraordinary, too, to relate, prussic acid, iodine, and some other poisons which poison the ferments of living things, also paralyse or destroy the action of metallic colloids.

Further steps breaking down the partitions between the organic living and the inorganic dead were made within recent years by Emil Fischer of Berlin, who succeeded in manufacturing polypeptides—a stage in the manufacture of protein; and by Bayly, who succeeded in making carbohydrates by the action of ultra-violet rays on carbon dioxide in water. Modern physiology and biochemistry have shown, too, that many of the processes called "vital," which seemed to be restricted to living animals and plants, take place also in dead matter. Osmosis works as well through dead parchment as through living membranes. Respiration is essentially a process of oxidation such as takes place in burning coal or rusting iron. Muscular force is of much the same nature as the explosions of dynamite, and heat in the body is changed into mechanical movement exactly on the same principle as in a steam engine. Indeed, all the motor and, it must be admitted, all the mental phenomena of life have behind them energy derived from chemico-physical sources.

"To-day," says Jacques Loeb, "everybody who is familiar with the field of chemical biology acknowledges the fact that the chemistry of living matter is not specifically different from the chemistry of the laboratory. . . . A measurement of the quantity of CO formed, and the amount of heat produced, gives approximately identical results in the case of a burning candle and a living guinea-pig." "The chemical processes of life," writes Carl Snyder, "are no whit more mysterious than the chemical processes which produce salt, or sugar,

or glass, or result in the burning of coal in the grate." "The magnet," says Haeckel, "that attracts iron filings, the powder that explodes, the steam that drives the locomotive are living inorganics; they act by living force as much as does the sensitive mimosa when it contracts its leaves at a touch, or the venerable amphioxus that buries itself in the sand of the sea, or man when he thinks."

With most of that I agree; we cannot make much *chemical* distinction between living organisms and dead matter, and it would be most extraordinary and anomalous if we could, considering that both are made of exactly the same atoms with the same chemical affinities and properties, and it must be admitted that all the considerations we have mentioned give a kind of presumptive historical and scientific probability to the theory that organic life arose—and by parity of reasoning can still arise—from the dead organic atoms by the same kind of chemical linkages and combinations that are seen when, for instance, hydrogen, oxygen, and sulphur link and combine to form sulphuric acid, or when carbon, hydrogen, and oxygen link and combine to form sugar. We are even encouraged to accept the daring evolutionary theory that the first cell formed had merely to go on making the usual chemical combinations between its atoms and between its atoms and the atoms of its environment in order to grow from am amœba into a shark, and from a shark into a man. Nevertheless, I venture to assert that the evolution of living organisms from mud under the

influence of ordinary chemical affinities is unproven, and not only unproven but extremely unlikely.

However confidently and dogmatically the doctrine of a mechanistic anoetic evolution of inorganic atoms into living matter may be preached, I assert, not only that it is unproven, but that it is extremely improbable, for the mud is still here; it has been here under competent scientific observation for hundreds of years; all the elements in earth and air and water that the theorists postulate are here, and yet scientific men admit that life never occurs unless as progeny of former life—that when all life is destroyed and the medium sterilised—and sterilised the Earth's crust certainly was—life never occurs. The fact that life never occurs in a sterilised medium is a matter of life and death, for on its truth depends the safety of aseptic surgery.

For centuries, it is true, men believed in this spontaneous generation of life from dead matter. Thales of Miletus maintained that animals were formed from moisture. Anaximander taught, like modern science, that life had origin in organic mud. Aristotle believed that frogs and eels could be developed from dead matter, and lays down the law: "Every dry body becoming moist and every moist body becoming dry engender animals." Virgil, in the *Georgics*, gives instructions how to produce bees, and down to the eighteenth century most scientists agreed with these ancient writers. Philippe Buonanni, for instance, a learned Jesuit of the seventeenth century, maintained that animalcules or small living creatures—*e.g.* mussels—

could be produced by spontaneous generation out of inanimate substances such as mud or sand, and averred that certain wood after rotting in the sea produced worms which engendered butterflies which became worms. In the eighteenth century, Buffon, Francesco Needham, and other famous men still clung to belief that worms and eels could be spontaneously generated. "It is very strange," caustically remarked Voltaire, "that men should deny a Creator and yet attribute to themselves the power of creating eels." But in the nineteenth century, after raging controversies, it was finally established by Pasteur and Tyndall and others that spontaneous generation never occurs, and in 1864, Pasteur, lecturing at the Sorbonne before a large distinguished audience, spoke the following dramatic words: "And therefore, gentlemen, I would point to that liquid and say to you, 'I have taken my drop of water from the immensity of creation, and I have taken it full of the elements fitted for the development of inferior beings. And I wait, I watch, I question it, begging it to recommence for me the beautiful spectacle of the first creation. But it is dumb—dumb ever since these experiments were begun several years ago; it is dumb because I have kept it from the only thing which man cannot produce—from the germs which float in the air—from Life, for Life is a germ and a germ is Life. Never will the doctrine of spontaneous generation recover from the mortal blow of this simple experiment.'"

Towards the end of the century, Bastian claimed that

he had seen spontaneous generation of low forms of life in sterile organic infusions; but his claims were shown to be unfounded, and it is a scientific axiom to-day—an axiom on which, as I have already mentioned, aseptic surgery is based—it is a scientific axiom to-day that every living thing has had its parent—*omne vivum ex vivo*—and that life never begins *de novo* in sterile mediums. Yet still evolutionists and biologists, and, I regret to say, some theologians, talk and teach as if it were a proven fact that living protoplasm arose from the concourse and combination of inorganic atoms. Some biochemists even look forward to the day when workers in biochemical laboratories will be able to create low forms of life, and seem to imagine that Emil Fischer's synthesis of polypeptides and Baly's synthesis of carbohydrates is a big step in that direction. But one does not make a sugar palm by making a lump of sugar, nor a lachrymal gland by making a tear.

Bateson, a few years ago, said that to suggest that the making of formaldehyde is the first step in the manufacture of life reminded him of Harry Lauder in the character of a Glasgow schoolboy pulling the treasures out of his pocket and saying, "That's a washer for making motor-cars."

With becoming modesty the creative optimists merely aim at creating low forms of life—forms lower even than protozoa—forms that they believe to have been the seeds of all living things—forms so low that nobody has yet seen them. But to talk in that way of low forms of life seems to show ignorance of the amazingly

complex nature of the lowest organisms we know. In a germ-cell there are said to be something like 8,640,000,000,000,000,000 atoms grouped in 1,728,000,000,000,000 molecules. A liver cell has been estimated to contain 300,000,000,000,000 atoms in 64,000,000,000 molecules, and has been compared in its chemical and mechanical complexity to a *Mauretania* full of chronometers. The work done by a proliferating bacterium, too, is quite comparable, bulk for bulk, to the work done by a rampaging rhinoceros, and there is at least as much complexity in a *seemingly* simple human ovum as in an adult man. It may be noted, too, that E. B. Wilson, who probably knows more about cell life and cell structure than any other living man, has stated that " the study of the cell has on the whole seemed to widen rather than to narrow the enormous gap that separates even the lowest forms of life from the inorganic world ; while L. J. Henderson, in his interesting work *The Order of Nature*, admits that " the advance of science has assuredly not made the origin of life easier to imagine or even to think about." On the contrary, that " it has made the task far more difficult."

To talk of low living organisms, then, seems to show ignorance of the complexity of living organisms. Further, such primal organisms, if we are to believe evolutionists, must have been constructed in such a way as automatically to evolve into the million forms of life, and would require to have almost incredibly intricate and, I think, presciently arranged chemical complexes. If evolution be a fact, then an amœba has greater

chemical potentialities than a man, and it should be at least as easy to make a human ovum by chemical processes as to make the simplest of the protozoa or one of their predecessors.

Does any one really believe that chemists will one day make a lowly organism chemically so constituted that simply by a long series of chemical processes and selection it will grow into a Shakespeare ?

Those who think that chemists will one day create life are on the horns of a dilemma; either they must, as evolutionists, believe that in creating the lowest form of life they will be creating the seed of all living things up to man, or they must become fundamentalists of a sort, and believe in special creation by themselves and in the fixity of the species they happen to create. Personally, I am quite unable to believe that there are elements to-day "fitted for the development of so-called inferior beings." I am unable to believe it, because they are never found to develop, because all scientific experiments prove that life to-day never develops except from life, and also because such a belief logically leads to such grotesque consequences as the creation of a man. As a rational man, I am bound to conclude that *if* at the beginning of life atoms did run together into living protoplasm then they had affinities, and modes of action, and contents of energy such as they certainly do not have to-day. It is quite possible, it seems to me, indeed, not altogether unlikely, as I have argued in my book *Heredity, Evolution, and Vitalism*, that the chemical rudiments—notice I am talking only of the chemical

rudiments—of the protoplasmic *materies* of life may have come directly from the nebula in the form, as suggested by Professor Pflüger of Bonn, of some such chemical compound as " cyanogen," which is formed at incandescent heat, and which possesses great quantities of internal energy. It is also quite possible, too, that there were large ultra-radio-active atoms—lucid atoms —then in existence, and that they had " something to say " in the chemical reactions that took place in these fiery days, or that rays such as the cosmic rays co-operated. These are possibilities—so far as they will carry us—but it is most improbable that dead matter, as we know it to-day, ever became living protoplasm, under the chemical and the physical forces we know to-day.

Two of the greatest minds of last century, however, Lord Kelvin and von Helmholtz, realising that in our experience life only comes from life, and laying down abiogenesis as a general law—" Dead matter," said Kelvin, " cannot become living without coming under the influence of matter previously alive. This seems to me to be as sure a teaching of science as the law of gravitation "—explained the sudden occurrence of *life* on our sterile planet by the interesting and picturesque theory that germs of life had been brought to earth tucked away in the cracks and interstices of meteoric stones.

Kelvin's particular theory was that a planet covered with vegetation got smashed in a collision, and that fragments carrying seeds or spores or living plants and

animals fell upon Earth. "One such stone," he argued, "falling upon the Earth might, by what we blindly call natural causes, lead to its becoming covered with vegetation."

The great Swedish astronomer Arrhenius, on the other hand, believed that germs of life escaped from fertile planets may light on barren ones and thus introduce life.

There are many obvious objections to both these theories. Firstly, there is little reason to believe that there is plant or animal or vegetation on other planets. Secondly, it would be passing strange if living organisms from other planets fitted so well into our special conditions of soil, air, water, heat, and light as to grow and thrive. Thirdly, the origin of life from dead matter would still have to be explained, and if it could take origin on another planet, why not on the planet Earth?

But at least these great thinkers—unlike the biochemists who think that they can create life in a laboratory, and unlike the evolutionists who believe that the chemistry of ordinary elements under present-day conditions might give rise to it—these great thinkers at least faced facts and realised that matter, as we know it here to-day, does not and cannot become protoplasm, far less a protoplasmic organism.

Personally I prefer the theory of cyanogen nuclei. It is absolutely unscientific and irrational to assume, contrary to all evidence, that atoms, *such as are the atoms to-day*, can, by their chemical affinities, grow into the chemical compound, *living* protoplasm.

Further, every living thing we know is not merely a chemical compound—a homogeneous mixture of molecules—it is much more: it is various compounds combined into an intricate structure as interdependent in all its parts as the works of a watch. A seed is not merely a chemical compound, it is an architectural arrangement of various chemical compounds; and chemical reactions, so far as we know—and rational science does not go beyond knowledge—combine atoms, or separate atoms, but do not arrange and orient groups of compounded atoms into co-operative societies. Still further, while the chemistry of *formed* living tissues may be the ordinary chemical reactions seen in a test-tube, and while the extraordinary processes of growth and the extraordinary equilibrium between katabolism and anabolism—between waste and repair, that is to say—may *possibly* be largely explicable on chemical principles and stated in chemical formulæ, yet there also occur apparently purposive reorientations and rearrangements of structural units which are never seen in any chemical mixtures or compounds and which cannot be explained by chemistry or physics. I refer to processes of growth, of repair, of locomotion, and reproduction. When the cell divides there are movements molar not molecular, and apparently *purposive*, regulating the inheritance of the units in it, known as "chromosomes," and it is impossible to explain these movements merely by chemico-physical processes. And the result of the division—the reproduction and co-ordinate combination of traits

characteristic of the parent cells—has nothing in common with chemical reactions. So, too, the arrangement of the cells to build up the holistic architectural forms in the embryo that end in the perfect animal cannot be fully explained by any chemical reactions. Huxley remarked that as we watch the cells of the ovum arrange themselves into a living body it is almost as if an unseen hand was moulding them into shape. Nor can the movements of the tiny cells, the osteoblasts and osteoclasts, which build and mend the bones and seem to show a knowledge of stress and strain, be explained by chemico-physics. All the processes, indeed, of growth and repair display a wonderful versatility and a wonderful adaptation of means to ends. Cells, that never did such a thing in their lives before, reconstruct organs and tissues according to correct plan, and if the old way of reconstruction be debarred even invent new ways of reconstruction. It is a most remarkable thing, too, and a thing chemistry cannot explain, that quite inexperienced cells may deputise for the cells usually employed. If, for instance, the lens of the eye of a triton be removed, it is reconstructed by the cells of the iris—cells which, moreover, are of quite different origin from the cells that normally construct the lens. More remarkable still, if in the *Salamandra maculata* the lens be removed and also the cells of the iris which have been found able to reconstruct it, cells of the inner layer of the eye undertake the reconstruction of the lens. Thus cells differently born and differently constituted are able to act for each other and do an expert's

work, and such substitution is quite common in living processes. Obviously cells could not show such prescient and intelligent adaptability and versatility if bound by the rigid chemical and physical laws that rule dead atoms. In the characteristic processes of life there seems to be an impetus from an ideal prospective whole which for its own realisation and its own service produces and co-ordinates impulses in the parts. Die Pflanze bildet die Zellen nicht die Zellen die Pflanze. *In all the processes of life there seems to be an arrangement and re-arrangement and a co-ordination of units in order to reach a definite end for a definite co-operative whole, quite apart from the chemical factors that are the source of the energy and that may play some part in the movement.* My fingers are composed of certain chemicals, it is chemical energy that moves my pen. If my blood did not get a little oxygen my fingers would cease to move; no doubt they are moved by little chemical explosions, but it is not chemical explosions that *make the movements purposive* and weave them into a whole, it is the something that was added to matter when in the crust of the Earth living things first were made.

We cannot explain the beginning of living protoplasm by any chemical reactions that occur to-day, and though, as I have said, we might *possibly* explain the chemical *constitution* by assuming chemical compounds and forces existent then and no longer existent to-day, we cannot explain the *functions* of life by any chemistry or physics at all. However great resemblances there

may be in the molecular phenomena of the dead and the living, there is also still greater distinction which no science can abolish and no chemical theory explain—a distinction ultimately as great as the distinction between a statue of Shakespeare and his body—between a bottle of ink and his books—a distinction so great that my reason demands a Mind to explain it, and a distinction so vital that my imagination feels the Breath of a Creator. Life is not a chemical product; its directed energy is more than chemical reactions, and the functions of living cells cannot be explained by any chemical processes whatsoever. So far as facts go and evidence goes, we must consider life as a directive influence apparently noumenal in character superimposed upon dead matter, and hold with Virgil that "mens agitat molem et magno in corpore miscet."

It seems to me that, in its investigations of Life, Science has achieved more than it has yet realised, for it has compelled all rational logical minds to postulate a Creator. To-day we dare not dismiss Deity with Laplace's "Sir, je n'ai pas besoin de cette hypothèse"; rather must we say with Voltaire, "If there were not a God it would be necessary to invent One"; rather must we say with Leibnitz, "Actualia dependent a Deo, tum in existendo, tum in agendo" (not only the existence but the activities of things depend on God); rather must we agree with Huxley's opinion that "the honest and rigorous following up of the argument which leads us to materialism inevitably carries us beyond it."

Far the greatest of modern Science's great discoveries

has been this yet only half-realised discovery of God. It will be said by many that it leads only to confused thinking to postulate unknown forces, unseen causes, and invisible fingers, and that science does not deal with abstractions. But more and more science does deal with the unseen and invisible and its ultimate analyses end in symbols, and abstractions, and mathematical equations. If even physiology talks of volition, and voluntary muscles, and mental processes, and sensations, surely it is legitimate to postulate a Mind and a Will when only they seem sufficient to account for vital phenomena. The postulate of a Great Moving Will is just as scientific and just as sound as the postulate of personalities and conscious minds in the bodies of other men : it is a matter not of sight but of reasoning, and largely of reasoning from analogy.

Whatever the origin of vital matter and vital function, living matter must have appeared at some point in space and time, and, as most of us are not fundamentalists and interpret Genesis rather as inspired poetry than as accurate science, it will be interesting to speculate where and when and in what shape the first forms of life appeared.

As I have already stated, I see no reason at all to believe that unicellular organisms are simpler and lower than multicellular organisms, for, according to evolutionists, unicellular organisms held in them, and may yet hold in them, all the potentialities of organic life, and certainly it is a little unicellular organism—the human ovum—that grows into a man ; but the records

of the rocks seem to suggest that there was a serial emergence in the direction of gross anatomical differentiation of parts with physiological differentiation of function, and that probably single cells independent, self-contanied, and *to all seeming* anatomically and physiologically undifferentiated, came first.

Some biologists surmise that some blob of protoplasm structurally much less complex than the single cells we know to-day appeared first. That seems to me an idea founded on unsound reasoning. As I have said, if evolutionary theory be correct, the first cells must have been extraordinary complex cells ; but even apart from evolution, surely a chemical compound able to move, to digest, to breathe, to duplicate itself, must be of most intricate complexity. The first living cell was probably a cell with all the chemical complexity and structural intricacy of the cell we know to-day, and however made —we do not know *how* it was made—its time and place of appearance must have been largely a matter of temperature. So long as the crust of the earth was red-hot no cell, as we know cells to-day, could live, and the first cell probably appeared when and where some part of the earth's surface fell to a suitable temperature. It is usually assumed, therefore, that life first appeared about two thousand million years ago in the muddy water of the ancient world.

In 1802 Lamarck wrote: "In the waters of the ancient world and at the present time very small masses of mucilaginous matter were collected. Under the influence of light certain elements, caloric and electric,

entered these little bodies. These corpuscles became capable of taking in and exhaling gases, vital movement began, and thus an elemental plant or animal sprang into existence." In 1809 Oken expressed the opinion that every organic thing rose out of the sea slime, and that all living things were merely different kinds of organic slime that had originated as chemical compounds from the inorganic. He believed that man also was born in this way and came, like Aphrodite, from sea foam. "Man," he declares, "also is the offspring of some warm and gentle seashore, and probably rose in India, where the first peaks appeared above the water. A certain mingling of water of blood-warmth and of atmosphere must have conjoined for his production, and this may have happened only once and at one spot."

To-day the view is usually expressed that life arose where the crust first cooled—in the warm silt of circum-polar seas; but I think that a prettier, more probable, hypothesis is that life first appeared in a warm puddle on the peak of a lofty polar volcano. The hot steaming crust of the primal Earth must have been lain for long in darkness, and not only would the peak of a lofty polar volcano be the first part of the crust to cool down, but it would be the first part to issue forth from the clouds and see the sun. It is possible, as I have said, that rays of the sun that no longer reach us may have played a part in forming protoplasm out of the mineral matter in the volcano-puddle; while it is quite certain that, even if formed, living matter could not be maintained alive unless the sunrays made carbohydrate food for it.

All life to-day, as we shall shortly see, depends on the manufacture of carbon and protein compounds in plant cells, and in the air round the volcano there would be plenty of the raw materials, carbon monoxide, carbon dioxide, methane, and there would also be a certain amount of nitrates dissolved in volcanic water or formed in the air by lightning and suitable bases for protein manufacture.

That is my own theory, and it seems to me quite a plausible hypothesis, that the first living organisms came to birth or rather was created on the peak of a volcano —offspring of fire, and mire, and lightning, and sunbeams, *and mento-volition.* It may have belonged to the Algæ species, the Confervidæ (found to-day in hot springs), as they tolerate higher temperature than any other unicellular organism, and are able to feed on inorganic matter.

It is also quite possible that life first appeared in a lightning cloud. But wherever it appeared there must have been some power at work not at work to-day, and a power exercised apparently by a prescient will.

Now let us look at the problem of life from another large standpoint. Life, we must all admit, is the climax of Creation. The blossoming of Life from the Dust, whether the inevitable consequence of a series of chemical changes or of " Breath from the Nostrils of God," was certainly, is certainly, one of the most marvellous phenomena the Universe can show. Flowers, and trees, and birds, and beasts, and men are certainly to us more wonderful than any lifeless blazing sun, than any huge

dead nebula, however vast. It may well seem to us, the highest Blossom on the Tree of Life, that Life must, in some mysterious way, be the real meaning of everything. And yet think what an ultra-microscopic speck life is! All the teeming life of our globe—all its forests, and meadows, and gardens—all its myriads of fishes, birds, and beasts, and men, and microbes, is in material bulk so small that it might all be buried in the Pacific without appreciably raising the sea-level; while if it were all made up into a ball and flung into the crater of a sunspot it would be licked up like a speck of dust in a roaring furnace, it would vanish like a withered leaf in the cauldron of a volcano. The amount of this magic matter in comparison with any big aggregate of matter in space is quite insignificant.

Sprinkled through space for countless millions and billions and quadrillions of miles there are, as we have seen, two thousand quadrillion suns, all full of tremendous atomic energy, representing incredible amounts of matter, yet all of this energy so far as concerns the consummate and crowning creation of Life seems wasted.

Personally, I do not believe that from the point of view of Life it is really wasted, I believe that Life is such a big thing that, even as the pull of the moon may save the life of a starfish, and as the grindings of a glacier may prepare soil for a gentian, so it is possible that "every star is needful for a rose," or a prelude to something even more beautiful. Yet, to all appearance, the flaming suns are merely bonfires, or at best beacons. Consider how many wasted years there seem to have

been, what prodigal waste of material there seems to have been in the preparation of our little speck of protoplasm, even if we restrict our estimate to our own nebular history. For life has been on this planet only about a thousand million years—man only a few hundred years, and yet the nebula from which we came began some five million million years ago. Five million million years of combustion! What waste of fuel—of heat and light—of power it might seem! And what seeming waste of matter! During these five million million years of Sturm und Drang almost all the original atoms of the nebula have been converted into radiation, and have, *as matter*, been annihilated for ever. In the Earth to-day there are only a few radio-active atoms —the atoms of uranium—left, and all the great lucid atoms which probably formed the bulk of the nebular material have either broken down into simpler and lighter and more permanent atoms or have vanished altogether. What is left to-day in the crust of the Earth is simply a tiny residue of ash. Yet until all the other atoms had been abolished or broken down, Life was probably impossible, for our experience of radium have shown us that radium in bulk kills, and therefore all the five million million years of toil were necessary to disrupt the radio-active atoms and to prepare—as it did prepare—the elements carbon, nitrogen, hydrogen, oxygen, sulphur, phosphorus, etc., which are required in the material of life protoplasm—to prepare and to arrange them by volcano, and cloud, and river, and sea, so as to render them available. Can we look back on

this tremendous preparation for millions of years—on the nebula, on the crashing suns, on the slow destruction of lucid atoms all undoubtedly leading to life, without realising the mystery of protoplasm, without having a Vision of a Mind behind the Advent of Life, without believing that so infinite a Past seems to point to an immortal Destiny.

This leads us to the very interesting question as to whether there is life on other planets. It is a question that has been much discussed, usually by astronomers or physicists, who with a limited view of the intricate relationships of life, have come to the conclusion that since there are thousands of quadrillions of suns all seemingly with the same atoms as the Earth, the likelihood of life on some of them must be considerable. Arrhenius, for instance, and Kelvin both believed that there must be plenty planets besides the Earth homes of living things. But those like Russel Wallace, with a deeper knowledge of the structural and environmental inter-relations and intricacies of life, and the amazing concatenation of circumstances required to make life possible on our planet, have believed that Earth is the only planetary or stellar abode of Life.

One point that seems to have escaped most, if not all of these who have considered the question, is that life—whether it required special creative interposition or not—is a matter not of one planet or of one sun, but of a planet and sun working in most intimate and intricate association. There would be no life—at least none of the higher forms of life—on Earth to-day, what-

ever its atomic condition might be, if there were no central sun. It was gravitation, and the breakdown or abolition of radio-active atoms, together with some small amount of oxidative combustion, that produced the heat in the original nebula, and it was these together with the tidal tug of the passing sun that put heat energy into our Solar System ; and all the members of the Solar System may be said to be sharing a common fund of energy derived from these sources. But it was the special energy segregated in the sun that lifted the clouds, and kept the rivers flowing and prepared the vital mud ; and rays from the sun—rays that no longer radiate—very probably took part in the unique chemical reaction that produced protoplasm. And it is certain that to-day the Earth has not enough of its original heat to maintain life, and that without the warmth of the sun all life would perish and the world become barren deserts and ice-fields. Equally certain it is that the energy in the carbohydrates in the green plant is the source of all animal energy, and that the energy in the carbohydrates is derived from the energy of the sun. Further, our relationships to the sun are very complex. Were we farther away we should be frozen. Were we nearer we should be roasted. A little more ultra-violet light and we should be slain. Indeed, were it not to-day for a layer of ozone in the outer atmosphere, the sun would slay us as it slays microbes.

Also, as we pointed out, our mode of origin from a shattered sun is very unusual, " our sun with its family of attendant planets is rather of the nature of an

astronomical freak," for out of a thousand million stars there are not more than ten thousand planetary systems. That in any of these planetary systems there should be another planet so happily and fortunately related to its sun, and dowered like our planet with all the hundreds of inter-related factors favourable to life such as we know it—that there should be on the universe another planet so amazingly like the Earth as to possess all its vital advantages, seems to me extremely unlikely. Those, of course, who imagine Martians comparable to men imagine very foolishly and ignorantly, and cannot have considered the multitudinous intricacy of a man's mind and body. Regarding life even as an evolutionary or chemical problem, it is quite plain that a very small molecular difference in the seed, or a very small variation in environment, would have completely altered the end product. Man and his environment, life and its environment, fit together as accurately as a million keys and a million keyholes, and the slightest alteration in a single key or keyhole would render it impossible to unlock all the gates of life, at least as we know life.

What is the meaning of all these suns burning away to ashes, we do not know; but seeing that the ashes of the Earth after five million million years have blossomed into life, we may, at least, dream that the stars are more than altar torches, that something more wonderful even than their flames is preparing in the flaming suns.

Living things, then, as I see them, are made of a chemical substance, protoplasm, possibly collected round nuclei which had their origin in the fierce fires of

the contracting nebula, and possibly compounded and energised with the assistance of lucid atoms now annihilated. Its *materies* probably required for its making millions of years of gossamer weaving, and of fiery forging, and the idea of making it in a laboratory is absurd, for not only is it improbable that we can ever make the protein molecules of the life substance, but it is almost certain that the initial weaving of the molecules and micellæ into a functioning structure was not entirely a matter of chemistry or physics, but a spiritual matter of the same kind as the moving of a pen.

Lord Kelvin, an acute philosophical thinker as well as a great physicist, held that there was something in life quite outside the scope of scientific analysis, and when he asked the great chemist Liebig if *he* believed that a leaf or a flower grew by chemical reactions, Liebig answered "that he would as readily believe that a book on chemistry or botany could grow out of dead matter by chemical forces." I agree with Liebig, but I would go further, for I would point out that if one believes that a single cell is a product of mere anoetic chemical processes, one must also logically attribute to anoetic chemical forces all that comes out of the cell, including man and all the books in the British Museum.

Science here has achieved more than it has yet realised, for it shows us in Life a mystery that stretches in light and darkness to the utmost star—a mystery equally interwoven with the mystery of matter and of mind, and with the great mystery of a Creator.

CHAPTER V

THE CHEMISTRY AND CHEMICAL ENERGY OF MAN, AND THE PHYSICAL BASIS OF HEREDITY

"Thou dost this body, this enhavocked realm,
Subject to ancient and ancestral shadows,
Descended passions sway it: it is distraught
With ghostly usurpation, dinned and fretted
With the still tyrannous dead; a haunted tenement
Peopled from barrows and outworn ossuaries."

FRANCIS THOMPSON.

"Born into life man grows
Forth from his parents' stem,
And blends their blood, as those
Of theirs are blent in them,
So each new man strikes root into a far fore time."

MATTHEW ARNOLD.

WE have seen Man as the blossom of a nebula: we have analysed him into whirling electrons and protons: we have groped for his roots in the puddle of a volcano. Now let us look at him as a finished chemical product and as a living organism among living organisms.

First let us consider from the chemical side his chemical substance, *protoplasm*. Personally, as I have already indicated, I do not accept the view that all the functions of living things came from the inorganic simply by a series of chemical reactions, or that any chemical

reaction can completely account for them. I do not even accept the view that the constitution of protoplasm was built up by such energies and chemical affinities as we know in the inorganic world to-day, nor the view that it can ever be artificially built up by any chemical and intellectual means at our disposal. Still Man's body, like all other living bodies, is made up of chemical substances, and these chemical substances react with each other and with their environment, and provide the energy and the conditions for the larger co-ordinated vital functions. So it will be interesting to glance at the chemical side of Man.

The protoplasm of Man's body consists mainly of a complex of large nitrogenous molecules—micellæ—composed essentially of carbon, hydrogen, oxygen, nitrogen, sulphur, and sometimes phosphorus, with the addition of a few free salts such as sodium chloride. None of the constituents are particularly noteworthy: all are quite common and can be found even in the head of a lucifer match. Of the five principal elements, three—oxygen, hydrogen, nitrogen—are gases, while the other two, carbon and sulphur, solids. Hydrogen is found in the gases of volcanoes and combined with oxygen it is found in water. Oxygen is one of the gases of the air and is a constituent not only of water as mentioned, but of the common gases carbon dioxide and carbon monoxide. Nitrogen is also one of the gases of the air, and is also found compounded in ammonia and nitric acid. Sulphur is found in the gases and deposits of volcanoes.

The gases as gases have volatility, mobility, and versatility. Nitrogen, though inert and exclusive, has explosive tendences. Oxygen is very sociable and essentially the combustive element. Carbon has an extraordinary faculty for linking elements into compounds, and is able to make itself into either coal or diamonds or graphite. But really there is nothing about the elements of life that would make them seem more vital than, say, iridium, or helium, or uranium, or magnesium, or gold. Yet essential to life they are, and if they had not been ready-to-hand in the crust and atmosphere just in the forms they are, just with the special physico-chemical qualities they have, there would not have been any life to-day on our planet, and if they had not been present in abundance there could not have been such fecundity of life. Had any single one of them been omitted from the crust, not a single living thing could have been born, yet there are dozens of other elements that seem of little or no vital use at all.

The way in which the elements of life have come to hand is rather remarkable, for there can be no doubt, as we have already said, that carbon, hydrogen, oxygen, nitrogen, and sulphur were all in the first place volcanic products—all belched from volcanoes, and that water was volcanic steam. So that certainly in the stages of inorganic evolution on the Earth prior to life the part played by fire and cataclysm in the preparations for life is quite evident, and we may be excused in surmising that every stage in the long process of inorganic evolu-

tion from the nebula to air, water, and mud, all led to and worked for the same great consummation—Life.

If we analyse Man's body quantitatively we find in a man of medium size—so it has been calculated—at least enough hydrogen to fill a ten-gallon barrel, enough oxygen to nearly fill nine hundred nine-gallon barrels, enough carbon to make ten thousand lead pencils, enough phosphorus to make nine thousand boxes of matches, enough hydrogen to fill a balloon capable of lifting him to the top of Ben MacDhui, enough iron to make five carpet tacks, enough salt to fill six ordinary salt-cellars, and four or five pounds of nitrogen. Regarded then, chemically, Man is mostly gas and water.

Now, let us consider the chemical energy in Man's body and the very interesting part played in it by the gas carbon dioxide. Carbon dioxide is the transparent odourless colourless gas which we see bubbling in aerated waters. It consists of one atom of carbon (which in its solid state we know as coal, diamond, or graphite) linked to two atoms of oxygen. Its primal source in the world, like most of the materials of living tissues, was the volcanoes, but to-day it is produced in large quantities, not only by volcanoes, but by the combustion of wood and coal and by the respiration of animals. In the atmosphere there are only three parts in ten thousand of this gas ; but without it there could be no life at all ; for it is its carbon that goes to form plant starch and plant protein, and it is from plant starch and plant protein that animals get the carbon required to make the proteins of the protoplasm of

their cells. The carbon dioxide in the atmosphere passes into the interior of the green leaf by little mouths called "stomata," and with the aid of sunlight certain cells in the leaf break it up into its components carbon and oxygen, and rejecting part of the oxygen build up the carbon into starch and sugar. In the starch and sugar the radiant energy of the sun assumes chemical form, and it is this transformed radiant energy in the green food which gives herbivorous animals energy to move and to build up their tissues—an energy passed on in chemical form as protein to animals, such as tigers and men who eat flesh. The carbon dioxide is the corner-stone of every vital edifice. Had volcanoes not belched it forth there could have been neither protein nor starch in the world, and yet in large amounts it is a deadly poison—it is the gas which poisons dogs in the grottoes of Vesuvius—and a little more carbon dioxide in the atmosphere would have been fatal to all life. Indeed it is probable that the mighty primal volcanoes did eject fatal amounts of carbon dioxide which rendered animal life impossible till great quantities of the gas combined with lime as the carbonate of lime mountains that we see in the world to-day, and with the vegetation whose carbon we now use as coal. It seems then as if lime mountains, the Alps, etc., and coal, were necessary preliminaries in the making of man, and that when the Maker made the mountains He was really engaged in making a man. And even now there would soon accumulate fatal quantities of carbon dioxide were it not that such great amounts are broken up and used by

green vegetation to make starch and sugar, and were it not that the sea acting as a sort of automatic safety valve absorbs into solution and locks up some of the gas whenever it forms in excess. Thus is maintained one of the many myriad delicate equilibriums on which life depends. We may say that life depends on the gas that we know as bubbles of aerated waters, but we must add that no marble no man. It is ignorance of these finely adjusted equilibrations and adaptations—there are thousands of them—that make the ignorant and imaginative see Martians digging canals and cultivating parsnips, and make even scientists sometimes believe that living protoplasm may be made as one makes a cake of soap, and the evolution of a whole complicated inter-related holistic organism might be altered by stimulation of a single gland.

We shall return to the question of the energy in carbohydrates when we deal with energy more fully ; here I merely wish to point out that all living cells, whether or not originally compounded by special primal radiant energy, are certainly to-day energised by the sun through the medium of the carbohydrates formed by sunlight in the cells of green plants. We never move a limb without the assistance of a sunbeam that came 93,000,000 miles to assist.

Man, then, regarded as a multicellar organism, is kept alive and moving by the activity of vegetable cells, and his chemical composition and chemical reactions depend fundamentally on the chemical composition and chemical reactions of the grass of the field, and still more

fundamentally on the radiant energy of atoms in the sun. The more, indeed, we regard Man from cellular and chemical standpoints, the more we see how infinitely far stretch the roots of his life, the more we see that in his veins run both sap and sunbeams, and the more, too, we must recognise that there must have been some sort of mento-volitional prescient providential arrangement of such a huge adaptative co-ordinated complex as volcanoes, and the sun, and the green cells, and Man's body, and activities imply.

The manufacture of carbohydrates in the green leaf has been called "the central fact in life on this planet." Let us look a little more deeply into the process, and see if we can understand its chemistry, for it is probably a purely chemical process. Let us look, too, more closely at its relation to energy and to the building up of animal tissues.

The plant with the aid of sunlight breaks up the carbon dioxide into carbon and oxygen, and with the further aid of sunlight it uses the carbon to build up carbohydrates. How are these chemical processes achieved? We must answer that, though hundreds or thousands of scientific workers have been trying to solve the great secret of the green leaf, the secret is still unsolved. The carbon dioxide absorbed through the wonderful little mouths on the surface of a leaf goes into green cells containing the complex pigment chlorophyll (which is chemically akin to the red pigment hæmoglobin of the blood), and passes into solution in the cell sap, so that the little green cell becomes, as it

were, a little green bottle of aerated water. Then the sun shines and as if by magic the carbon is torn from the oxygen. The oxygen bubbles out (as can easily be seen by watching a water-lily leaf under water) while (as can easily be seen by a microscope) grains of starch form in the cells. Now, how is it done? The carbon and dioxide in the carbon dioxide are very firmly bound together—so firmly bound together that chemists can tear them asunder only by violent means, *e.g.*, by passing the carbon dioxide through red-hot tubes or by putting burning magnesium wire into a jar of the gas. Yet, the great sun, ninety-three million miles away and the microscopic green cell do it coolly, and silently, and easily. And starch, chemists cannot make, yet sun and green leaf make it without any trouble. It may be the chlorophyll pigment which fluoresces under light and reduces waves of light of high frequency to waves of lower frequency, which is chief chemist in the process, or it may be that the little colloid bodies which contain the pigment and which absorb the light (and appear therefore, under light, black like specks of soot), are the real starch-makers. We do not know, the whole process, which is the central fact in life on this planet, remains a mystery.

Within the last few years the bio-chemists—Baly, Heilbron, and Barker—have succeeded in producing the poison "formaldehyde" by the action of short ultra-violet waves of light on carbon dioxide in water, and have also succeeded by the further action of larger ultra-violet waves on the formaldehyde in converting

the formaldehyde into carbohydrate. That is an interesting chemical achievement, and may eventually shed light on the secret of the green plant; but it is certainly not in that way that the green plant forms its carbohydrates.

The carbohydrate starch or sugar is as a bridge over the ninety-three million miles of space between the sun and the Earth. Each tiny grain of starch in each tiny cell contains as it were a sunbeam, or at least the radiant energy of a sunbeam, in chemical shape, and when we eat either carbohydrates or proteins, we are feeding on transformed sunbeams whose energy will be the source of our vital activities. In this shape the energy can be conserved and stored for æons. It is the carbon of the green leaf carbohydrates that gives heat energy to our coal, and when Gimbernat drank soup made from a mastodon's tooth he was really putting into his blood sunbeam energy collected from green vegetation by a molar tooth hundreds of thousands of years before—he was releasing from the tooth sunbeams that had been imprisoned in the cold storage of the gelatine for perhaps a million years. "What a chequered career," as I elsewhere remarked, "the carbon in Gimbernat's soup may have had—volcano, green leaf, mastodon's tooth, soup, stomach, blood, brain-cell!"

Let me repeat that all the energy we get from our food is primarily red sunlight. Each of us is Sa Ra; son of the Sun, and draws from his father's sunbeam banks the energy of life. Like Nebuchadnezzar, we are

all grass-eaters, though we may use an ox's or a sheep's grinders to chew our grass, and every molar that munches hay is munching sunbeams. Life is not a planetary but a helio-planetary phenomenon.

The energy contained in carbohydrates is very great, as we see when we burn oil or sugar. Every ear of wheat hanging in a field of wheat is an explosive bomb, and a pound of wheat contains enough latent energy to pitch itself about fourteen miles.

The importance of carbohydrates is shown not only by the abundance of green vegetation that clothes to-day so much of the crust of the planet, it is shown also in the marvellously ingenious and delicate way in which leaf-structure is arranged to facilitate the energy and manufacture of the gas. On the under-surface of some leaves there are million little mouths to allow entry of the air, and it seems to me that every mouth declares the art and ingenuity of the God who made them.

What locomotive energy, what heat, what potential conflagrations must there be in all the green meadows and forests of the world!

Seen as great factories of energy, forests and meadows and prairies acquire more imaginative worth: every green leaf reveals a crimson heart, every green blade of grass is a tongue of fire, and surely we ourselves who live on sap and flame acquire more importance.

The body of man, then, is made up of certain ordinary chemical elements compounded into protoplasm in some mysterious way energised by the sun, and it is

built up by the budding of a single cell—the human fertilised ovum. Let us see, now, if we can comprehend the manner of its building.

The duplication of the cell is preceded by a very mysterious rearrangement of its structural constituents, and this rearrangement appears to have a close connection with some of the facts of heredity, and especially with the facts of heredity in bisexual animals. We must, therefore, begin our consideration of heredity by a consideration of the structure of a cell and of those structural rearrangements which precede duplication.

A cell, as we have insisted, is not simply a blob of protoplasm, it has a definite arrangement of distinguishable parts. In its centre is a dense knotty-like speck, the nucleus, and between circumference and nucleus there is thinner, clearer, more transparent substance, the "cytoplasm."

Both the nucleus and the cytoplasm can be stained; when the nucleus of a human cell is stained with suitable dyes it is seen to be mainly composed of a sort of network made of a substance which stains particularly readily, and therefore has been called "chromatin," and this chromatin network seems to play a big part both in development and heredity.

Before the cell divides, the chromatin network changes into a long-looped and coiled thread, which in time breaks up into a number of rods or loops usually of equal length and thickness. These are called "chromosomes," and at times of division arrange themselves in belt form round the equator of the nucleus. At the same

time that this is going on a small transparent rounded body called the centrosome divides into two, and each gives origin to a system of fine fibrils which radiate from it like the ribs of an umbrella, and the two radiating systems are placed to each other in such a way as to make a kind of spindle. Nextly, the chromosomes split longitudinally into two—as one might split a firewood stick, and the halves, directed in some way by the spindle, move in different directions, and become segregated so as to make two new nuclei of the original network character. Thereafter, the original cell, which has been slowly forming a waist, divides into two halves —one half containing one nucleus and the other half the other. It will be seen that the manner of division distributes the chromatin of the old cell equally among the two new ones. In some way not understood, the centrosome is necessary for duplication, but how it acts is obscure. This whole process of division has received the appropriately long name of "karyokinesis." That is a very curious phenomenon, and it is difficult to see how it can be explained chemically. There are certainly no such molar manœuvres in inorganic chemical processes.

Every cell of every animal and plant of the same species has the same number of chromosomes. In the grasshopper there are twelve, in the ox and guinea-pig sixteen, in the mouse, trout, and lily twenty-four, in the snail thirty-two, in the shark thirty-six, in the little salt-water crustacean artemisia one hundred and thirty-eight, while in man, the house-bat, and the hedgehog

there are forty-eight. What exactly the numbers signify, and what are the biological correlations between numbers and characters, it is impossible to say, but the numbers must have vital importance otherwise they would not be so constant. In all the millions and millions of cells of a multicellular organism there is no variation in the chromosomic number, and when the cell divides the splitting arrangement already described maintains the original number in each new cell.

Those who hold a chemico-physical and evolutionary theory of life would find it difficult on such a theory to account for the phenomenon of karyokinesis, and to show how it could be initiated or developed by any process of variation and selection. There seems to be some sort of intelligence in the cell integrating the parts and the movements of the parts into a purposive pattern. Anyhow, the resultant process of duplication seen in the duplication of a cell is plainly more than the division of a globule of mercury or a ball of butter: it is a duplication of an organised body, and it duplicates the fundamental structure of the parent cell. In the case of unicellular organisms there is duplication not only of the fundamentals of parental structure, there is usually an almost precise reproduction both structurally and chemically of the parent. Two yeast cells are as like as two peas in appearance and identical in chemical character, and what differences may appear are plainly mainly due simply to differences of environment, which disappear as soon as original environmental conditions are restored.

But the body of man is not built up by the simple duplication of a cell. It is built up by a special kind of differential duplication which occurs in the course of the budding of a fertilised ovum. The budded cells depart *in batches* from the parent type both in structure and in function to form the complex community of a multicellular organism, which repeats, with small variations, the intermediate and final patterns of the multicellular organisms that carried the egg.

The ovum becomes a mulberry mass, the mulberry mass arranges itself into a hollow ball; the hollow ball becomes dimpled and the dimple deepens, and the ball becomes a double-walled cup (such as may be formed by pushing in an india-rubber ball), the cup divides into four layers and each layer forms certain organs. The skin-cells flatten; their outer layer grows horny to protect the soft parts; the muscle cells grow out into long contractile spindles; the nerve cells send out long prolongations called "nerves," so that a microscopic cell may extend from the spinal cord to the tip of the great toe. Other cells which are to perform digestive functions form ferments in their interior, while the cells that are to carry oxygen to the tissues develop the remarkable pink pigment hæmoglobin. The chemical functions and reactions of all the cells seem quite in accordance with ordinary chemical laws, and their energy is derived from ordinary oxidative and disruptive changes in their chemical molecules, yet their orientation into place, their sudden differentiation in constitution to suit various duties in the various

parts of the organism, are quite different from the duplication of single cells, and still more different from chemical reactions in test-tubes. All the cells work together for the common weal, even the millions of free cells which float in the blood or wander through the tissues. There is a common kitchen—the digestive organs; a common distributing agency—the blood; a common governing body—the brain; and cells communicate with each other and with the G.H.Q. by means of the nerve cords, and by means, too, of substances called "hormones" which circulate in the blood. The multicellular body of man is indeed an amazingly successful imperial dominion, where no cell lives for itself but each works for all and all work for each. Co-ordination is wonderful, insubordination very rare—except, perhaps, in tumours, where some cells multiply and grow at the expense of their neighbours and the community—and when any poisons or germ cells invade the commonwealth all the cells work together to defend the body politic.

Bound together as most of the cells are, yet each is an individual entity, able in most cases to live a completely separate life; and cells such as the cells of the skin and the muscle cells of the heart, can be cut out of the body and kept alive and multiply for months. Cells cut out of the heart of a fowl, and fed, and tended, have been kept alive for periods much exceeding the natural term of the fowl's life; and the cells of the skin if sown on a raw surface multiply and grow and form a membrane over it.

What is it that causes this beautifully opportune co-ordinated mutation of the cells in the embryo and their final architectural co-operative association in the mature organism? What is it that keeps the multicellular organism true to its multicellular type, while its individual groups of cells periodically depart so far from their parental paths?

Theory holds that every ovum buds directly from a previous ovum and every sperm-cell from a previous sperm-cell, and that the bud-cell chain is continuous at least as far back as the first man and woman, and we can say that the capacity to grow into a complex organism is inherited with the germplasm—that naturally bits of the same germplasm will develop on similar lines. But to say the capacity is inherited explains nothing, it merely throws the question a few hundred thousand years further back.

The question is—Can we by any consideration of the chemistry and physics of a fertilised ovum explain the wise coherent differentiations of its buds, and the opportune variations that take place in its crops of cells, and that lead to the final co-operation colony, the mature body?

It is believed that the budding and the differentiation of the buds is in some way controlled by particles of chromatin in the chromosomes, and attempts have been made to explain both heredity and development and variation on that basis, and many extremely interesting facts have been discovered, especially with regard to the influence of fertilisation and associated

processes on heredity and variation; but no explanation so far has really shed any light on the mystery.

We have explained the process of karyokinesis, which preceded the duplication of single cells; but the egg which in the higher animals produces the soma or body of the animal is not a single cell, but a blend of a male cell or "sperm-cell" with a female cell or "ovum." And in the higher animals there can be no reproduction without a conjunction or fertilisation. The single cells regarded in this connection are known as "gametes" and the conjoint cell is called a "zygote."

Now, before the gametes conjoin and form the zygote, each goes through a remarkable series of preliminary reconstruction in their nuclei, and it is in these and in the conjunction of the reconstructed nuclei that innate variations in offspring seem to have their origin, for if it is assumed that the characters of the multicellular animal are determined by its chromatin particles, it follows that blends and rearrangements and the compounding of new chromosomes will alter the chromatin inheritance and the developmental potentialities of the zygote.

In the unicellular animals—even though evolutionists postulate their evolution—there is no such blending and reconstruction, only a splitting of the chromosomes into equal parts, and so far as we see to-day the buds vary neither in bunches nor individually.

Let us look, then, at the extraordinary reconstructive processes that go on in the gametes.

The ovum of the higher animals is usually a round

piece of protoplasm about $\frac{1}{20}$th of an inch in diameter —about the size of a full stop. Like all other cells it has in its centre a nucleus which forms the number of chromosomes characteristic of the species. Since fertilisation consists essentially in the conjunction of the ovum and sperm-cell and the blending of their nuclei, the natural result would be a doubling of the chromosomes in the fertilised ovum. But prior to fertilisation occurs a process called *maturation,* which prevents such doubling.

Instead of each chromosome splitting longitudinally into two, as it does in ordinary duplication, the chromosomes in the ovum amalgamate in pairs, so that the number of separate chromosomes is halved and the thickness of each doubled. Thereafter each amalgamated chromosome is divided by tranverse section into two, and the halves collect themselves into two nuclei, which become the nuclei of two new cells, one large and one small, formed by division of the ovum. The smaller one, called the polar body, plays no part in development and heredity. The larger proceeds to divide in the usual way by splitting its nucleus and dividing the split chromosomes between two cells so that each has the same number of chromosomes as itself, *i.e.* half of the number of the chromosomes originally in the ovum. These two cells are mature ova ready for conjunction. In a similar way the sperm-cells reduce the number of their chromosomes and with half the original number become mature sperm-cells ready for conjunction. Accordingly, when conjugation occurs and both gametes,

the male and female, join in the fertilised cell or zygote, they merely restore the chromosomes to their original number.

The processes that take place in the course of the fertilisation of the ovum are rather too complicated to be explained here, but the main facts are that before conjugation the chromosomes of the male and female cells go through complicated shufflings and additions and substractions, and accordingly if—as is the theory—the chromatin of the blended nucleus of the fertilised egg determines the development of the offspring, then the offspring will show likenesses to its parents, but also exhibit variations. The blend will not be a blend of the whole chromatin of the two parents, but a blend or patchwork of selections from the chromatin of each; and the characters of the offspring will therefore be like those of the two parents and yet different.

The rearrangement of the chromatin in the gametes and the blending of the nuclei, though certainly instrumental in variation, cannot be the sole instrument, for variation occurs in some of the lower animals which reproduce without fertilisation.

Exactly how the chromosomes and chromatin particles act in transmitting hereditary characters and producing variations is a moot question. The most famous theory is Weismann's theory of determinants. He assumed that every character of the body capable of independent variation—such, for instance, as the colour of the eye—has alternative representatives both in the male cell and the female cell in the shape of

special chromatin particles which he called *determinants*. Some of these determinants are rejected during the process of maturation which precedes conjugation, but even in the fertilised ovum there are alternative determinants contained in the male and female chromosomes. When the cell differentiates and the characters begin to develop, all the determinants—maternal, paternal, and ancestral—compete for a place, and in the end the man is a mosaic of the characters that have won places in the competition. The successful determinants are, as it were, distributed at the right time to the various mutating cells, and determine their mutations and the course of their development. The fertilised ovum contains them all, and all of them are passed on to the first cells budded off, which are thus themselves ova, but by degrees the determinants are allotted between the budding cells, which thereafter have no longer the versatility of an ovum, but have to fulfil definite destinies. Weismann further supposed that many of the cells carry extra latent determinants which come into action when mutilations have to be repaired.

Weismann's theory is little more than a picture in concrete terms of the fact that children do inherit traits from their father and mother and ancestors, and really does not explain how they are carried by the chromatin or how they are built up into the body. Granted determinants, the question remains *how* are the determinants distributed so wisely and opportunely to the various cells, and *how* after distribution do they deter-

mine the cells into definite forms and places and relations.

The study of fertilisation merely shows us that the process and its preliminaries rearrange and redistribute the chromatin of both ovum and sperm, so that conjugation of ovum and sperm give to the fertilised ovum so much of the chromatin of each parent. And that, of course, suggests that the chromatin is the physical basis of the likenesses and unlikenesses that are found existing between offspring and parents, and between the children of the same parents. It helps us to understand heredity, but throws no light at all upon the actual form in which the traits are carried, or how with their aid the complex multicellular body is constructed out of the material of the germplasm. The traits-of-the-body may have separate location in the cells and be handed down in the form of determinants from cell to cell; but how the single cell, the size of a full stop, distributes these in the course of its duplications, and builds them with its food into the intricate web of the body, is a complete mystery which has no counterpart in inorganic physics or chemistry. Even such an apparently simple function of a cell as budding has been seen to be a process of intricate complexity preceded by a delicate reconstruction of the whole cellular structure—a structure, be it remembered, that may be composed of some ten trillion atoms.

Could we understand a single cell in its simplest functioning, " we should understand what God and man is." But we do not in the least understand, and, as we

mentioned before, Dr. Wilson, who knows more about cells than any other man, confesses—as we have already mentioned—that study only deepens the mystery.

In the cellular elaboration and architectonics, as in the case of the first origin of life from the inorganic, there seems to be an immanent directive power using and directing the energy, and orienting the particles, much as a writer directs and orients the black fluid ink that winds across the writing paper. Reason demands an explanation; and I can find no other rational explanation. The cell is not only an agglomeration of enormous complex molecules of protein—which I believe possibly had their origin under chemical conditions no longer existent, and derived their energy from sources of energy no longer in action—the cell is not only such a peculiar conglomeration of matter and energy, but seems to be guided in its whole behaviour by some force kin to mind or will. The stuff is star-stuff; but the motive power, spirit. "Es ist der Geist der sich den Körper baut."

It must be admitted that the making of the marvellous body of man is very like a miracle—a miracle at least in the sense of being far beyond human comprehension and human achievement, and infinitely remote from the reactions familiar to us in inorganic or organic chemistry of the laboratory. "Why, who makes much of a miracle?" asks Walt Whitman:

"To me every hour of the light and the dark is a miracle,
Every square yard of the surface of the Earth is spread with the same,
Every foot of the interior swarms with the same."

At least, let us confess the mystery and the miracle, even if we deny that there is a theo-thaumaturgist in and through and behind them.

But though we do not understand the development of the body nor the material, or, as I should prefer to say, mento-mechanistic basis of heredity, we have discovered some very interesting laws of heredity and some actual facts with respect to the locations in the chromosomes of certain apparent "determinants."

One of the most interesting of the laws of heredity yet known was discovered in 1865 by a German priest Gregor Johann Mendel, in the course of experiments in his cloister garden on crossing peas. He found that if peas with contrasted characters were crossed only one of the two contrasted characters appeared in the hybrid. The character that in such a case appeared he called the *dominant*, and the character that receded out of sight or disappeared, the *recessive.*

Thus, when he crossed green peas and yellow peas, all the peas were green—green being dominant and yellow recessive. But he found that the yellowness was still in the green pea, for if he interbred the green hybrids one in every four turned out to be yellow, and that if he further interbred the second lot of green peas two out of three still produced one yellow to every three green, and that if he interbred the third crop of green peas still two-thirds of them produced one yellow to every three green, and so on, and so on. Whereas the recessive yellow peas, and one out of every three

green peas, bred pure, and, however often interbred, still produced only its own colour.

We see the same relationship interestingly exemplified in the colour of eyes. If a member of a blue-eyed race with no brown eyes in the family marry a member of a brown-eyed race with no blue eyes in the family, the brown will prove dominant, and all the children will have brown eyes. But if the children marry mates with similar mongrel eyes, one in each four of their offspring will have pure blue eyes, and one will have pure brown eyes, and two will have mongrel brown eyes, while the mongrels intermarrying will again repeat these one, two, one proportions.

That was an interesting discovery that Mendel found, for it is a true and interesting explanation. He explained these constant ratios by assuming that though the contrasted characters appeared in the hybrid offspring, as if in a blend where one overpowered the other, yet the determinants of each contrasting character were carried quite separately and in equal numbers in the ovum and sperm of the hybrids. Thus, among twenty ova there would be ten with determinants for blue eyes and ten with determinants for brown; and among the twenty sperm cells there would be ten with determinants for blue eyes and ten with determinants for brown. And in such a case, if the sperm-cells and the ova paired at random, it would be found that there would be twice as many blue-browns (or hybrid browns) as blue-blues (or pure blues), and twice as many blue-browns (or hybrid browns) as brown-browns (or pure

browns). If one assumes the separations of the characters in the ova and sperms the chance combinations will work out on that ratio—$(x+y)\times(x+y)=$

On exactly the same principle, when several contrasted characters occur in male and female, the ratios in which the various combinations will appear can be calculated. Mendelism, as the principle is now called, was worked out in great detail by Bateson and others, and it has proved of great value to plant and animal breeders, enabling them to make useful combinations of character and to separate pure from mongrel species. But still its application is limited to certain contrasted characters, and not all contrasting characters Mendelise.

As a more general law we know that children are mosaics, made up not only of characters selected from their parents, but also of characters handed down in the chromosomes from ancestors—characters which have failed to appear for generations. The proportions of characters contributed by parents, grandparents, and further back ancestors was calculated by Galton, who enunciated the following Law—called the *Law of Ancestral Inheritance.*

The two parents between them contribute *on the average* one half of each inherited faculty, each contributing one quarter of it. The four grandparents contribute between them one quarter, or each one sixteenth, and so on, the sum of the series $\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}$ . . . . being equal to 1 as it should be.

Karl Pearson by biometric calculations found the

contributions of parents, grandparents, and great-grandparents to be 0·6244, 0·1988, and 0·0630 respectively—figures near enough to those of Galton.

The conception of a mosaic inheritance makes, I think, an appeal to the imagination. In one sense the child is an individual: in several senses he is a community. In one sense he is a "chip of the old block," in several senses he is a parqueterie composed of many blocks. He has only one heart, one brain, one liver, a couple of lungs, and a couple of legs, but he is of cells innumerable compacted and of functions innumerable compounded. He is a determinate being, but his ontogeny is determined by millions of determinants, and the very determinants are chosen from incalculable myriads of candidates.

One of the most striking scenes in Maeterlinck's play, *The Blue Bird*, represents the unborn children waiting on the shores of life for Time to bear them. But the making of a child is far more wonderful, mysterious and complicated than any allegory can suggest, and the sciences of embryology and development are simply crammed with miracles.

According to modern embryology and genetics, there wait on the shores of life not children but innumerable alternative potential fragments of children. Every male and every female seed-sperm and germ is a little packet of such fragments competent to form a complete infant. Further, when germ and sperm join, the fragments are mixed together and the final result is a product of this mixture. For instance, in the germ

there may be a fragment to colour the child's eye blue, and in the sperm a fragment to colour the child's eye brown, and the two fragments will blend to form a brown eye. Or a fragment (unseen for generations) handed down from a great-grandmother on the mother's side, and a fragment (unseen for generations) handed down from a great-grandfather on the father's side, may blend and produce an atavistic or perhaps a novel character.

The laws that govern the transmission and mixture of these fragments—or "genes" as they are now generally called—are very complicated, but the net consequence is that the child is a kind of mosaic composed of maternal and paternal contributions. Even a thorough knowledge, however, of the characters patent in father and mother will not enable us to predict with certainty the child, for, firstly, both father and mother have latent genes in them that have not come to light in the course of their own development, but that may come to light in the blended offspring: and secondly, the blending of the genes received from father and mother may produce characters unlike the characters they represent when unblended. This is the reason why some parents sometimes have insane children, and dark parents blonde children, and stupid parents clever children.

In discussing heredity, one must refer to the stupid question so often put—are acquired characters transmissible. It is a stupid question, for *all* characters are acquired by development of rudiments in the germplasm of a fertilised egg, and are, of course, transmissible as rudiments in the germplasm. The germplasm, how-

ever, that goes to the making of a child does not include the whole rudiments of either the paternal or maternal germplasm, but a combined selection from both, and the transmission of any special character depends on whether the rudiments of that character are or are not in the dual selection. Put otherwise, the characters any organism acquires are those determined by the chromatin particles in the fertilised egg which produces it, and it transmits just as many of these characters—no more and no less—as are represented in the fertilised egg which goes to make its successor.

The stupid question is probably intended to inquire whether the development of a parental character ripens in any way its rudiments in the parental germplasm, so that children start the development at a less rudimentary stage and carry it farther. That was, of course, the theory of Lamarck, but it is certainly not the case. So far as a father or mother transmits rudiments of characters to a child, they transmit them unchanged by any parental developments, and so far as the developments of these characters is concerned, the child starts just where its parents started, and the extent to which it may develop the characters is unaffected by its parents' development performances.

Now, then, what is Man ?—dust on a snippet of a nebula—miniature solar systems and ether—mud from a volcanic puddle energised by sunbeams—a bud on a chain of life millions of miles long—a mosaic made of bits of dead ancestors. What is Man seen in all these lights ? He is, at least, a mystery.

CHAPTER VI

DIGESTION AND THE DIGESTIVE GLANDS. THE BRAIN

"The health of the whole body is tempered in the laboratory of the stomach."—DON QUIXOTE.

"True it is, quoth the belly,
That I receive the general food at first
Which you do live upon: and fit it is,
Because I am the storehouse and the shop
Of the whole body: but if you do remember
I send it through the rivers of your blood
Even to the court, the heart—to the seat of the brain
And through the cranks and offices of man.
The strongest nerves, and small interior veins
From me receive that natural competency
Whereby they live."

"*All flesh is grass* is not only metaphorically but literally true, for all these creatures we behold are but the herbs of the field digested into flesh in them, or more remotely carnified in ourselves. Nay, further, we are what we all abhor—anthropophagi, and cannibals, devourers not only of man but of ourselves, and that not in allegory but in positive truth, for all this mass of flesh which we behold came in at our mouths, this frame we look upon hath been upon our trenchers; in brief, we have devoured ourselves."—SIR THOMAS BROWNE, *Religio Medici.*

IN the next two chapters we shall deal briefly with some anatomical and physiological facts relative to the body as a going concern. We cannot, of course, here go into the facts very fully, but we hope at least to demonstrate the intricate ingenuity of its structure and functions.

Energy, growth, repair, and reproduction, all depend on processes usually summed up in the term "digestion." In the main, these processes consist in the absorption and assimilation by the cells of solutions of certain substances—foods. If the substances are not naturally soluble they are rendered so by certain so-called "ferments"—digestive "ferments." Unicellular organisms like bacteria and amœbæ take their food in a way beautiful in its simplicity, they just crawl in it or swim in it and absorb it as they crawl or swim, and if it be solid, their general surface secretes ferment to dissolve it. With abundance of food, such as a jug of soup or milk, such unicellular organisms grow and multiply with tremendous rapidity, so that there may be hundreds of thousands of bacteria in a single drop of milk, so that we usually buy in milk a good deal more than we pay for. Some bacteria, such as the cholera bacillus, can absorb and assimilate its own bulk of food in twenty minutes, and might thus in one day become 5,000,000,000,000,000,000,000 with a weight of about 7366 tons, and would form a mass as big as the moon. In multicellular organisms no cell, not even the divising ovum, can rival digestive feats like that partly owing to commissariat difficulties, but chiefly owing to different vital constitution.

In the higher animals (and plants) digestion, though similar to digestion in unicellular organisms, is more complicated. A higher animal cannot feed simply by swimming in a tank of milk, and he can absorb through his skin very little food of any kind. The food is taken

into a sac and a long tube—the gastro-intestinal canal—and if not naturally soluble and absorbable, is rendered so by ferments secreted by special cells in the canal, in the liver, and in the pancreas. The food thus rendered soluble and assimilable, is carried by the blood to all the cells, and the cells thereupon act after the manner of unicellular cells and imbibe it by their general surface.

That in a general way is the process of digestion, and even stated thus roughly, seems to involve foresight, ingenuity, and marvellous chemical skill. Let us now look at digestion rather more in detail, as it occurs in a man, and it will perhaps be best first of all to glance at the general chemistry of food and its relations to the energy, growth, repair, and reproduction of living tissues.

The constituents of the body-protoplasm, as we have already several times stated, are mainly carbon, and hydrogen, and oxygen, and nitrogen with some sulphur, phosphorus, and salts added. It is obvious, therefore, that if protoplasm is to be built up or repaired, it must be supplied with a substance containing in itself all of these or with several substances which together contain all of them. But it is not enough that the substance or substances contain all the elements required, they must contain them in an assimilable and energising form. A man fed on carbon and nitric acid, or on diamond dust, and carbon-acid, and potassium nitrate, will die, even though these substances contain all the elements required. And it will be found that, as a matter of fact, no substances are utilisable for building

and repairing unless they have come from previous living matter, either vegetable or animal. This may seem unreasonable and fastidious on the part of little Mary; but little Mary is a scientist with some one thousand million years of experience, and realises that she must put sunbeams into the blood before she can do anything at all, and that she cannot build up the protein in the protoplasm unless she can get bits of previous proteins to build with. All our food substances must contain the energy of the sun, and be in such form or be reducible to such form that the locked-up energy of the imprisoned sunbeams may be released in the living cells by means of the oxygen supplied to them by the blood, and that have been formed in plants (or in animals through the mediation of plants), are found to be energy-giving, and *even then only under certain conditions*. Coal, of course, is full of solar energy: it was made by the sun in plants, and the sunbeams can be released by oxidation: but oxidation of coal takes place only at temperatures far above the temperature of the living body. Grass and hay also contain sunbeamy carbohydrates; and herbivorous animals find in it all that they require, but the carbohydrate is in such a form that our human digestive ferments fail to render it soluble, and we can make use of energy locked up in grass and hay only by eating some herbivorous animal after it has dissolved the grass and hay and built them up into protoplasm. In the same way, there are plenty of nitrogen and plenty of energy in nitrates—which in some cases are energised by a lightning

flash passing through the nitrogen and oxygen of the air, but no animal digestions can get the nitrogen and the energy out of them until the plants, by their own special ferments, have built them up into vegetable proteins. Sunlight, and rain, and lightning, and roots, and green leaves, all play a part in making food for us, and Nature takes just as much trouble in making vegetable protein as in making vegetable carbohydrates to supply us with energy. We have mentioned that a single leaf may have a million little mouths to allow the entry of carbon dioxide, and it has been estimated that the roots and rootlets of a single stalk of wheat if put end to end would stretch 12½ miles. Think of that, roots groping around for 12½ miles to find the nitrogen for a few ears of wheat! That again to me seems to show a prescient persistence in the pursuit of a great purpose. Suns, rootlets, lightning, leaves, all are in a great conspiracy to make food for animals, so that even though we cannot thrive on coal and peroxide of hydrogen, and saltpetre, and such like delicacies, yet we have a magnificently various *menu* containing such different things as strawberries, and green peas, and turtle soup, and lobster, and trout, and egg, and oil, and sugar, and grapes, and tomatoes, and snails, and birds' nests, and caviare, and *pâté de fois gras*.

Regarded chemically, foods may be divided into three main classes: (1) Those which contain carbon, hydrogen, oxygen, and nitrogen—such foods are called proteins. (2) Those which contain carbon, hydrogen, and oxygen, with the last two elements occurring in them in the

same proportions as in water—such foods are called carbohydrates. (3) Fats and oils which also contain only carbon, hydrogen, and oxygen, but in which the proportions of hydrogen and oxygen differ from the proportions found in water.

Foods of the first class are sometimes called "nitrogenous" foods, those of the second class and third class non-nitrogenous. Lean meat, the white of egg, plasmon, skimmed milk are examples of protein food. Sugar and starch are examples of carbohydrates, and butter and cod-liver oil examples of fats and oils. Most foods, however, as they occur in Nature, and as we eat them, are mixtures of two or three different kinds of food substances. Meat, for instance, usually has fat with it, and there is fat, too, in the yolk of the egg. A potato contains both starch and protein, and a grape both sugar and protein.

Since protoplasm contains nitrogen, nitrogenous food is required to build up and repair the living tissues, and we cannot live on oils and carbohydrates alone, though by themselves they supply plenty energy.

As is well known, forms of energy are interchangeable, chemical energy can be changed into heat or electricity, and thermal and electric energy into energy of motion. Now it is possible by combustion to change into heat all the latent chemical energy in any food substance, and by measuring the heat to measure the total food energy. All eating is heating.

The unit of measurement used in estimating the heat is the calorie, *i.e.* the amount of heat required to raise

1 lb. of water 4° F. (more accurately one kilogram of water one degree Centigrade) and (in terms of energy of motion) that amount of heat is the equivalent of work performed in raising one ton a foot and a half, or in raising a ton and half one foot.

So measured, we find that an ounce of protein food such as lean meat, or an ounce of carbohydrates such as sugar, contains 116 calories, *i.e.* enough energy to raise a ton 174 feet, and that an ounce of fat contains 263 calories, *i.e.* enough energy to raise a ton 394 feet —all that energy coming originally from the sun in the form of radiations. On these figures it might be imagined that the best way of obtaining energy would be to eat plenty of butter and oil, but the energy obtained from food depends not only on the energy contained in the food, but on the digestibility and combustibility of the food in the body, and fat in large quantities is not very digestible, nor is it nearly so combustible in the body as outside the body. As a matter of fact, it is found that for energy purposes in the body protein foods are quickest and most effective; and as a matter of experience it has been found that the best dietary is a mixed dietary containing substances belonging to all three classes, proteins, carbohydrates, and fats. A certain amount of protein is always necessary, as we have mentioned, to supply nitrogen for the protoplasm, and it is possible that some of the small races like the Japs who have lived mainly on rice, which contains little protein, owe their small size to lack of nitrogenous building material. In most cases,

however, there is a tendency to add too much rather than too little protein to the dietary, because many protein foods are tasty and appetising; and a few years ago an American business man, Horace Fletcher, Professor Chittenden of Yale, and Professor Hindele of the Nutrition Institute, Copenhagen, showed, while most people take three or four ounces of protein in their daily dietary, one or two ounces—that is less than the amount in an egg—is all that is *necessary*. The Scotch, too, who produce a fine race on porridge (a food containing comparatively little protein), also demonstrate the same fact. On the other hand, protein food is not so fattening as carbohydrates and fats, it is less bulky, and it seems to give more active energy, so that a little more protein than is necessary is probably advisable.

In a general way, a dietary must have a certain amount of protein with an addition of enough carbohydrate and fat to supply the energy and building material the body requires, and it must vary with climate and with the size and constitution and physical and mental activity of the individual. As a rule 2 or 3 ounces of protein, 2 or 3 ounces of fat, and the rest carbohydrate, is a good diet.

An average man can keep alive and healthy, and do an average amount of work, if supplied with food containing 2000 or 3000 calories of energy—that is, with enough energy to lift a ton weight 3000 to 4500 feet. That seems a good deal of energy to use in a day, but only a small proportion of it goes in voluntary muscular action, most of it is used by the heart and the organic

functions, and to keep up the heat of the body. A very powerful man doing a very hard day's labour, such as a long distance bicycle ride or a cross Channel swim, may consume sufficient food to produce 10,000 calories of energy. But the amount of calories obtained from any dietary depends not only on the food but also on the digestion.

The body requires not only carbon, hydrogen, oxygen, and nitrogen, but also sulphur and phosphorus and mineral salts and water and some substances called "vitamines," but these are all contained in an ordinary protein, carbohydrate, and fat dietary. Vitamin A, for instance, is contained in butter, vitamin B in the germ of grain, vitamin C in oranges, and Vitamin D in milk; while, of course, there is plenty phosphorus and sulphur in eggs.

After this very brief sketch of the nature of food, let us see how food is digested and built into the tissues, and used as a source of chemical and mechanical and electrical energy.

Digestion may be said in a sense to begin at the moment food is seen or smelt, for the sight and smell of food excite the secretion of the digestive juices: the mouth, as the saying is, "waters" and the stomach waters, too. But without food in the digestive canal to digest, such preliminaries are wasted, and it is perhaps more correct to say that digestion begins when the food enters the mouth. In the mouth the food is chewed, and the chewing not only mixes it intimately with the digestive ferments in the saliva, but prepares it to be

swallowed and exposes it to the chemical action of the other digestive ferments in the stomach and intestine. The secretion of the ferment "ptyalin" in the saliva is stimulated through the nerves of taste and smell. Its digestive power is weak, but it splits some of the carbohydrates of the food into dextrin and maltose. Mixed with saliva and to some extent chemically altered, the food passes down the gullet into the stomach. The stomach is a muscular bag with muscles arranged in several layers round it, so that it can be gripped by them in all directions, and it has glands in its walls which secrete digestive substances. In this muscular bag the food is squeezed and churned and mixed with the gastric juice. The gastric juice is quite a remarkable chemical mixture, for it contains three different ferments—*pepsin*, *lipase*, and *rennin*—which have three different digestive functions, and also a small amount of hydrochloric acid. The pepsin and the acid acting together change insoluble proteins into soluble substances called peptones. The lipase splits fat into glycerine and fatty acid. The rennin curdles milk. The hydrochloric acid changes cane sugar into the sugars known as dextrose and lævulose.

Again there seems to me no getting away from prescient chemical skill.

The secretion of the gastric juice is stimulated, as we have said, by the sight and smell of food. It is also stimulated by the taste of food in the mouth. The main digestive function of the stomach is to convert insoluble proteins into soluble peptones.

From the stomach the food is pushed on in a semi-solid form—the chyme—into a long convoluted tube, the small intestine, and almost as soon as it enters this tube pancreatic juice from the pancreas (the sweet-bread) is poured over it. This secretion of pancreatic juice at the opportune moment is an illustration of the remarkable way in which all the cells of the body work together. The acid chyme again, the moment it enters the intestine, causes cells in its walls to secrete a substance, "secretin," and this substance is carried by the blood to the pancreas, and in turn stimulates it to secrete. The pancreatic juice is alkaline and neutralises the acid, and so no more secretion is formed and the flow of pancreatic juice soon ceases, but if another supply of chyme arrives the pancreas is again in the same way stimulated to activity. Is there not ingenuity in all that that compels us to postulate a marvellously ingenious far-seeing Mind?

The pancreatic juice is the most powerful of all the digestive juices. It contains three digestive ferments—*amylopsin*, which, like ptyalin, converts carbohydrates into maltose; *lipase*, which, like lipase in the gastric juice, converts fat into glycerine and fatty acids; and *trypsinogen*, which, when acted upon by a ferment in the small intestine called *entero-kinase*, becomes a ferment *trypsin*, which not only breaks up protein into *peptones* after the manner of *pepsin*, but further breaks the peptones into *polypeptides* and the *polypeptides* into small bits called *amino-acids*. That does not mean very much to those who are not chemists, but at least

it means that the trypsin of the pancreas breaks the protein into very small pieces.

Besides the ferment entero-kinase the small intestine secretes a ferment *erepsin* which, like trypsin, splits up peptones and other ferments, and also a ferment that converts the unabsorbable sugar maltose into the absorbable sugar glucose.

In the large intestine nothing of particular chemical interest happens; but like the small intestine it is swarming with micro-organisms, some of which promote the digestive processes. The net result of all these complicated chemical processes is to render things like beefsteak, and rice pudding, and plum tarts absorbable: they turn proteins which cannot be absorbed into absorbable amino-acids, and carbohydrates which cannot be absorbed into absorbable glucose, and fats which in their natural state cannot be absorbed into absorbable fatty acids and glycerine.

The next step in digestion is obviously absorption, and the arrangements for absorption are most ingenious and efficient. Contrary to general opinion the stomach hardly absorbs at all, and practically all absorption takes places in the small intestine, which is pleated, and folded, and studded with thousands of little projections, "villi," like the pile of velvet. In this way the superficial area of the small intestine is increased from less than two square yards to more than fifty yards, and over the whole fifty yards the glucose and amino-acids are vigorously absorbed as the mass of digested food is driven along and over it by the muscular squeeze of

the intestine. These again are surely clever contrivances that no mechanistic theory can explain. The fatty acids and the glycerine are mostly absorbed by little tubes known as "lacteals," which run inwards through the centre of the villi, and the cells lining the lacteals compound the fatty acids and glycerine into fat again which are eventually poured into the blood, so that after a fatty meal the blood may look quite milky. A good deal of fat thrown into the blood is stored in special cells, forming adipose tissue, and becomes a sort of reserve of energy to be drawn upon when needed.

The sugar glucose passes through the liver, and there is converted into another carbohydrate, glycogen, which is stored up in the liver cells, and given again to the blood in the form glucose as required. The amino-acids again, of which there are many kinds, are built up in the living cell into the protoplasm—a chemical feat that no chemist has yet accomplished—though, as we have said, Emil Fischer has got as far as polypeptides.

These, then, are the main facts of digestion put in cold scientific terms. But they are enough to show what wonderful ingenious digestions we have. The faculty began with the first germ of life, and to-day the foods are carried round by the blood, which is a stream of brine very similar to the briny water of the primal puddle in which life is believed to have commenced. The main improvements that the vertebrate animals have effected have been to invent machinery to crush

foods, to elaborate means of distributing foods, and to convert means of oxidising them. With teeth man as a vertebrate tears and crushes his food, by means of a pump and tubes and crimson water he distributes it, and by means of little red discs he sends oxygen round to every cell in the body. Also he has found it more convenient to half-digest his food outside the cells in special digestive apparatus—the stomach and intestines—and he has elaborated the villi and lymphatics to collect the semi-digested food and convey it to the blood. But most of the machinery and apparatus for collection, distribution, etc., was to be seen long before the Vertebrates. The polypes began the alimentary canal, the flat worms and round worms invented the vascular system and the blood and the teeth. So far as digestion goes, man is simply one of the many multicellular organisms, and has no claim to distinction. Yet, nevertheless, the process whether in microbe or worm or man is a mystery. We do *not* understand how glucose, and amino-acids, and fats are woven into the wonderful living tissues, how apples, and oranges, and oysters, and oil, and milk, and turnips are finally built up into the energetic tissues of life, and how the energy in them is used in such a co-ordinated way. I eat an apple, and in an hour or two some molecules of that apple, having undergone all the complicated processes I have described, are woven perhaps into a brain cell whose inherent energy—energy ultimately derived from the fall or the clash of electrons ninety-three million miles away—may move

a pen or an eyelid. Bishop Keble once remarked that when we eat we should say and think, "Dust to dust I commit," but it is miraculous dust with sunbeams in it, and it is better that when we take a meal we should think of the miracle about to be performed.

CHAPTER VII

THE BRAIN AND EYE

"There is more rationality in thy body than in thy best wisdom."
—ZARATHUSTRA.

THE digestion it is that builds and rebuilds and re-energises the body, and the most important of all its charges are the brain and nervous system. If it were possible to dissect away all the other tissues and leave only the brain, and a network of nerve fibres, and the organs of sense, and if they could somehow be supplied with food, we would have the most characteristic part of a man left—the part that thinks, and feels, and wills, and remembers. Therefore, we find that the brain is particularly well fed—that the supply of blood to it going almost straight from the lungs is particularly plentiful and pure and particularly well supplied with oxygen. Let us look now at some of the chief structural and physiological features of the brain.

It is a commonplace to us nowadays that the brain is the organ of thought and of conscious life; but it was not always so. The old Hebrews made other organs at least share the high prerogatives of the brain. The word "brain" never appears in the Bible, and we find instead such expressions as "His bowels yearned with compassion"—"His reins instruct him in the night

seasons "—" The Lord trieth the heart and the kidneys." Not indeed till the time of Galen was the brain put in a place of indivisible supremacy, and not till quite modern times did man realise all its important initiating, correlating, and regulating functions.

When we look at the brain with the naked eye it resembles a huge sweetbread or walnut. Its surface is all furrowed and fissured, and the furrows and fissures give rise to the folds known as the "convolutions" of the brain. It shows too a tripart construction—a large front section, the "cerebrum," divided into left and right halves, and a smaller posterior section, the "cerebellum." It is continuous below with the spinal cord which seems to swell into the big brain ball, and at its base various nerves are seen to enter into its substance. It is richly supplied with blood-vessels, and is covered by several membranes. When we cut it and examine it microscopically, we see that it consists of fibres coming from all directions and ending on the surface in a layer known as the grey layer, composed of millions and millions of little branching cells. Its weight is only about three pounds, and it consists chemically mainly of 90 or 95 per cent. of water, and some phosphorised fat. And this little mass of cells and fibres is supposed to be the *sine qua non* of mind and feeling, and consciousness, and volition. It is impulses starting from its cells that move the voluntary muscles, and it is impulses ending in its cells that seem to give us conscious sensations.

The human brain is much more furrowed and con-

voluted than any brain of any lower animal, and the intricacy and multiplicity of convolutions and furrows offers a larger surface for the layer of grey cells, and this, no doubt, has something to do with the superior efficiency of the human brain as an organ of thought and will and feeling. It is also much larger in proportion to the body than the brain of any other animal, and its frontal and prefrontal lobes are better developed; but though there is a general impression that the larger brains are the better, yet there is no fixed rule in this way, and we find that clever men may have brains of below average weight. The average human brain weighs 48 ounces, but the brain of Helmholtz, who was one of the most brilliant men of his day, weighed only 45 ounces; and Karl Pearson and Dr. Raymond Pearl, who analysed the weight of 2100 adult male and 1034 adult female brains of Swedes, Bavarians, Hessians, Bohemians, and English, found that the brains of the Bohemians were heaviest and the brains of the English lightest, and could not—we are relieved to learn—prove any relation between weight of brain and intelligence.

It may be pointed out, however, that comparative figures of weight must be considered in connection with the size and weight of the whole body, for the brain is not merely an organ of sensation and thought, it also plays a part in the muscular movements and in the unconscious organic processes of the body. In Aberdeenshire, Yorkshire, and Ayrshire, where men are biggest, hats are largest. It is probable that, other things being equal, the larger brains are the more

intelligent, but still more important than size is probably the fineness and intricacy of the nerve and cell network in the grey matter of the frontal sinus. It is these intricate networks that seem to be connected with volition, memory, and association of ideas. The main difference between the brain of the Primates—the order in which zoologists put man, and the order to which apes and monkeys belong—is the great extent and intricacy of the cerebral areas connected with sight and touch. In the lower vertebrates the main centre in the brain is the centre of the sense of smell, and, speaking from the standpoint of genetic evolution, human intelligence may be said to have branched off when in the lemurs the eye centres began to outstrip the nose centres.

At birth, it is interesting to note, the weight of the brain of a human baby is just about the same weight (300 grammes) as the weight of the brain of a gorilla or chimpanzee or orang. It is after birth that the human brain outgrows the brains of its Simian cousins, growing to five times its natal weight, while the Simian brains gain hardly any weight at all.

It is probable, as we have already suggested, that the higher intellectual and moral faculties are connected with the frontal convolutions, but their individual relationship is uncertain and obscure, and there are large areas in front which seem to be latent so far as intelligence is concerned. In fact, cases are reported where considerable tracts have been destroyed without injury to the mind. In one well-known case a dynamite

explosion drove a crowbar through the roof of the socket of an eye and it came out in the man's brow, carrying away part of the frontal convolutions, yet he recovered and his mental faculties seemed little if at all impaired by the injury. Another case is recorded where a man lost by pistol shot more than two teacupfuls of his brain and seemed to acquire more brains by the accident. It is not, however, a method of increasing brain power to be recommended. Quite possibly there are parts of the brain in an early stage of their evolutionary development, and though at present they perform no intellectual function they may do so later on.

Though the individual relationships of the various higher mental and moral faculties to the cerebrum are uncertain, and though parts of the cerebrum seem to-day to be dumb, it is quite certain that the cerebrum as a whole is closely associated with mental and moral faculties, for children born with the cerebrum wanting or defective are always idiots, and in a general way we can locate faculties in certain definite parts of certain convolutions. As long ago as 1861, a French physician named Broca, who made a post-mortem examination of a man who had died after suffering from shock and loss of speech, found that the man had had a hæmorrhage in a convolution known as the third left convolution (since known as Broca's convolution), and came to the conclusion that this area was the motor centre of speech. Soon after, the famous English neurologist, Hughlings Jackson, demonstrated that in certain cases of epilepsy there was disease in certain definite con-

volutions, and a year or two later experiments on dogs and apes proved that there were many definite motor areas. To-day, we can locate in the human cerebrum the motor cells of the toes, ankle, knee, leg, hip, shoulder, fingers, thumb, arm, eyelid, jaw, etc.; and can often diagnose the situation of cerebral tumours. We can also, in a general way, locate the brain centres of sight, hearing, smell, touch, and taste. Strange to say, the geography of the human cerebrum is not much guide to the geography of the brains of animals lower than the mammals. A fish can see and capture worms even after its cerebrum has been removed, and a frog without a cerebrum can perform co-ordinated movements with its limbs, and swim and crawl, and a bird without a cerebrum can fly and find a perch. On the other hand, a shark is rendered impotent if its cerebrum is removed, for with its cerebrum is removed its centres of smell, and it is the smell centres that control the movements of a shark. (I may mention *en passant* that the fact that sharks are motivated entirely by their centres of smell has made me wonder whether divers in shark-infested seas might not protect themselves from sharks by using scents offensive to the sharks.)

So far we have dealt only with the cerebrum, but there is also the bun at the back of the brain—the cerebellum—to be considered. It plays no direct part in the volitional life of man, but it co-ordinates muscular movements, and we certainly could not walk without it. If the cerebellum is diseased a man can only stagger and totter, and cannot properly balance himself. The

centres of balance in the cerebellum are stimulated by impulses sent to them from the eyes and semicircular canals in the ear and skin. All such impulses running towards the brain and terminating in cells of the brain are called "afferent" impulses, as distinguished from "efferent" impulses which run outwards from the brain and terminate at some distance from it. Afferent impulses from the skin and the eyes, and especially from the semicircular canals in the ear, reach the cerebellum and cause the discharge of such afferent impulses as are required to set in action the various muscles taking part in balancing the body. The movement of the fluid that takes place in the tubes of the semicircular canals excites through ingenious nerve connections just the right movements in the right muscles. It is a wonderful automatic balancing apparatus that the cleverest engineer in the world could not imitate, even if he had the power of making nerve cells, and afferent and efferent nerves, and could place them as he desired.

The most marvellous part of the human nervous system are the appendices of the brain, the special senses, and particularly the special senses of sight and of hearing—the eye and ear.

The eye is essentially a lens whose curvature can alter to suit the distance of the object in the field of sight. It collects and focuses ether waves of certain lengths upon a nervous plate or retina, causing there chemical or molecule changes which are carried by the great optic nerve to the nerve cells in the cerebral centres of sight. Till these nerve cells in the cerebrum

are stimulated we have no sight, and when in any way they are stimulated we have some sort of visual sensation. We see stars, for instance, when we have a blow on the eye, and Helmholtz believed that if we could graft the optical nerve to the auditory nerve and the auditory nerve to the optical nerve the thunder would make us see lightning and the lightning would make us hear thunder. But the lightning seen in such a case by the visual centres in the cerebrum, stimulated by the thunder through the auditory nerve, would not resemble the lightning as seen by the visual centres stimulated through the optic nerve, for the receiving surface, the retina, is constructed in a very elaborate way to respond to focused rays of light, and without the retina to assort the light rays and turn them into precise molecular movements, the sensation of light would not be much more than the stars produced by a blow—merely a chaotic disturbance in the nerve cells of the sight centre.

The retina is one of the most exquisite structures in the whole body. Though only $\frac{1}{120}$th of an inch thick, no less than twelve layers can be distinguished, and the layer next the optic nerve is composed of cells like rods and cells like cones standing close together side by side —3,000,000 rods and a still greater number of cones. In the rods is a purple pigment called the visual purple, which is believed to play a part in the chemical processes connected with the nerve impulse. In the optic nerve there are calculated to be 500,000 fibres.

Such is the delicate and elaborate apparatus that

received and concentrates waves of ether, and converts them into the molecular changes associated with vision in such a way that the longest waves of ether that break upon the retina create, when propagated along the optic nerve, changes in the nerve cells of sight that give us a sensation of red light, while the shortest give us a sensation of violet.

Ninety-three million miles the ether waves came from the sun, and countless millions of miles from distant stars, and, lo and behold, a lens is there to focus them, and millions of cells are all marshalled there to receive them and hand them on to five hundred thousand fibres and millions of brain cells.

What an extraordinary coincidence that the lens should be there to focus the light, and that there should be 500,000 fibres and brain cells sensitive to them, and arranged to receive them, and what an amazing result that the light so transmitted as mere radiant energy should give rise to the whole world of vision—to stars, and roses, and rainbows, and mountains, and seas, and to all the emotions they cause.

The evolutionists declare that the eye arose by casua variation and selection; but the variations in the millions of associated elements must have been precisely co-ordinated in their variations to produce the perfect apparatus of vision—the lens, the millions of cells in the retina, the hundreds of thousands of fibres in the centre of sight—and to produce the intricate association between these and the cells and fibres in other parts of the cerebrum. Is it possible to believe

that casual variation could work in such a co-ordinated way to produce such intricate inter-relations not only between thousands of fibres but between cells and fibres and waves of ether? Well, there may be some people credulous enough to believe that chance variations can produce relations as intricate and mechanically effective as the wheels in a watch; but can any one believe that it was by chance that these intricate correspondences came to mean in the consciousness the whole visible world? One must try to be logical, and if one succeeds in believing that an organ like the eye in its brain relations and its ethereal relations was produced by happy chance, then one must logically believe, too, that it was just by chance that these relations came to have conscious significance. It seems to me that if we attach to chance the meaning it usually bears (*i.e.* that the events that came forth were just as likely to be wrong as right), then an eternity of chance variations could not have produced the eye in all its physical and histological relations, far less its products in consciousness. I am not unaware that the argument from design is unpopular, and I have no desire to use the word or idea design, but what we have to explain is not only the physical intricacies and reciprocities and correspondences of the eye, but the *resultant apparition in consciousness of the visible world*, and if any one do not see evidence of prescience and intelligence in the exquisite instrument and its relationships, surely he cannot fail to see them in their spiritual consequences. I can, with some difficulty, imagine a man who had

never before seen a typewriter finding one on a desert and saying, " It is a very wonderful machine, and the parts fit marvellously well together and work well together, but there is no evidence of intelligence in it, all the same," but I utterly fail to understand how any rational man finding beside the typewriter a beautiful type-written poem could still maintain that there was no intelligent purpose behind the machine. Personally, I can imagine nothing more certain, more scientifically and logically certain, than that no casual variation could have possibly produced the apparatus of vision in its multiform relationships, and the apparitions in consciousness associated with the apparatus. Even to use the words casual and variation in such a connection seems to me to stultify their meaning.

Let us remember some of the other relationships and co-ordinations we have already mentioned. Let us remember that every cell in the brain is made up of whirling solar systems whose vital activity depends on the subtle work done in green leaves by ether waves, created by electrons 93,000,000 miles away. We have to face not only the fact that the cells of the brain are in such intricate purposive relationships to the other cells of the body, such as the cells of the retina and digestive glands and blood, and that they all came from a packet the size of a full stop: but we have to face also the fact that their energy is the energy of their electrons energised by electrons in the sun, and that it is the intimate relationship between their electrons and the solar electrons that is the material basis of sight.

But further. There could be no sight were there not the amazing cells and nerves of the eye and brain; but there would be no cells had there not been a shattered star to make a planet of the right size revolving at the right distance round a sun—had there not been volcanoes to manufacture steam and carbon dioxide and oxygen—had there not been rain to make mud—had not some of the mud grown into green cells. The marvellous intricate intimacy between the nerve tissue of the optical apparatus and the atoms in the sun is only one correspondence in a causally related network of correspondences in time and space that result in the marvellous spiritual phenomenon — sight. The activating correspondence between sun, ether waves, and protoplasm; the synthesising correspondence between chlorophyll, sunlight, and starch; the chemical correspondence between digestive ferments and foods; the mechanical and chemical correspondences between red blood cells, the blood, the heart, the air, were all necessary to lead to the correspondence between the electrons of the cells of sight and the ether waves of light resulting in sight. A cataclysm, a sun, a planet, volcanoes, clouds, rivers, plant cells, tiny germ cells, red blood cells, digestive cells, eyelids, eyelashes, lachrymal glands, ether waves of certain lengths, are all in relation and correspondence with the visual cells of the brain, and all co-operative in the final visual epiphany.

What an enormous, complex, multi-coloured, ubiquitous woof! What an infinite chain of lucky links of chance! What amazingly fortunate reciprocity!

The mind which fails to see a Theodicy in the eye of man seems to me logically deficient and spiritually blind.

Of course, much the same thing could be said of any of the organs or processes of the body, and we have chosen to say it of the eye and the cells of sight simply because the long, inter-related threads of the woof are perhaps brighter there than elsewhere.

We can trace the paths of excitation from the eye to the cells of sight in the brain, but why excitation of the cells should produce sensations of light we do not know: it is a mystery and part of the great mystery of the relationship between body and soul, matter and mind.

CHAPTER VIII

HEART AND BLOOD

" I conceive it will be manifest that the blood circulates, revolves, propelled and then returning from the heart to the extremities and thus that it performs a kind of circular motion."—HARVEY.

AS soon as multicellular organisms acquired size and complexity, commissariat difficulties supervened. Small sea organisms like the sponges and sea anemones had been able to get food for all their cells simply by immersing their whole body in a nutrient medium, but larger, thick-skinned organisms like sharks found that method of dining impracticable, and they had to contrive, firstly, a method of collecting and preparing food, and secondly, a method of distributing it far and wide. The contrivances for collecting and preparing food adopted in some form or other by the more complex multicellular animal organisms we have already described in our last chapter on digestion and assimilation, and we will now briefly describe the method adopted of distributing food by means of blood and blood-vessels. And here it must be noticed that before food can become available for energy-forming or tissue-forming purposes it requires to be oxidised, and accordingly compact multicellular organisms had to contrive not only a method of collecting and distributing food, but also a

method of collecting and distributing oxygen. This they did with great ingenuity—collecting the oxygen by means of special apparatus such as gills, lungs, branched tubes, and using a pump and the blood stream to distribute the gas along with the food.

The blood-vessels were one of the great inventions of the worm ; but blood in a sense there was long before the days of the worms. Its origin indeed might be said to have been contemporaneous with life, for to all intents and purposes the flowing sea from which the primitive organisms extracted their nutriment and their oxygen was blood—*blue* blood.

Blood is essentially water with some minerals, some organic substances, and some gases in it. The first water in the world came from the condensed steam of the primitive volcanoes. In this first water were minerals dissolved by the hot steam as it hissed through the crater mouth, and by hot cataracts running down lava boulders. In it, too, were oxygen and other gases, together with organic substances formed by the action of sunrays on the mineral solution. So that, chemically speaking, it was blood. Nature did more than draw blood from a stone, she drew it from red-hot lava, and the little rill that ran down the volcano ran on, and on, and on, till one day it flowed through the human heart. That sounds exaggeration, but it is simply an imaginative statement of a scientific fact.

The rills became streams, the streams grew to rivers, and the rivers in mighty hæmorrhage became an ocean of blood, in which the first creatures swam and fed as

in a great bowl of salty soup. The primitive sea contained all that sea creatures needed in mineral salts, albuminous substance, and oxygen. So rich and so nutritive, indeed, was this blood that in a short time the sea swarmed with little living organisms—trilobites, and radiolarians, and foraminifera, etc., which thrived and multiplied to such an extent that many of the great mountain ranges of the modern world are built of their little limy skeletons.

At the time life appeared in the sea (the sea of the Pre-Cambrian epoch), it had exactly the same proportionate chemical composition and temperature as has the blood of mammals to-day, and though the sea in the course of ages has grown much salter and colder, yet mammalian blood has obstinately and ingeniously maintained the original temperature of about 99° or 100° F., and is still a solution 8 parts in 1000 of some twenty or more mineral salts, with common salt preponderating — approximately the temperature and mineral constitution of the water of the Pre-Cambrian seas.

We are really aquariums, for all the cells of our bodies are bathed in dilute sea-water. The blood in our veins ran down the steaming craters of the Pre-Cambrian world; it is full of the mud of ancient volcanoes, and we still have much the same *menu* as the trilobites.

Of course our blood to-day is not derived directly from the sea brine, it is merely compounded from food and water according to the original formula; but so

closely is the original formula followed, that it is possible to substitute dilute sea-water for blood in the veins of mammals. When a person has suffered severe hæmorrhage, dilute sea-water can be put directly into his blood-vessels, and Dr. Quinton drained almost all the blood out of dogs, and kept them alive and vigorous simply by injecting warm sea-water into their veins.

But the blood of mammals is something more than dilute sea-water and something more than salty bouillon, for it is red ; and when we examine it under the microscope we see that it is full of tiny floating bodies, of three kinds—" white blood cells," " red blood cells," and " blood platelets."

The white cells measure, on an average about $\frac{1}{2500}$ of an inch, and in a tiny drop of blood there are thousands of them. Each of them is an independent organism, and so the blood is as full of water-creatures as was its ancestral sea. The white cells may be considered parasites, for they live not only in the blood but on the blood. Like many parasites they pay in some shape and to some extent for their board and lodging, for they produce substances fatal to disease germs, and in some cases they absorb and digest microbes that have entered the circulation. If the disease germs are outside the blood-vessels, the white cells pass mysteriously, like ghosts, through the vessel walls and mobilise in millions at the seat of invasion. Not only do they mobilise, but they multiply, and so form an ever-increasing territorial army. Often in the battle they suffer heavy

casualties, dying by the million, and their corpses form a large part of the white or yellow substance we call pus. It seems to me quite possible that in the costly and deadly struggle we have an illustration of the survival of the fittest, and that by a process of multiplication and selection a race of robust immune white cells is evolved. Anyhow, the white cells multiply, fight, and die, and in many cases conquer, or help to conquer, the invading microbes.

The white blood-cells are akin to the microscopic organisms called amœbæ found in ditch water, and very similar cells take part in the building of bone and in the formation of connective tissues. They crawl, and sprawl, and swim about, changing shape like drops of animated gum, and some of them, when they meet any foreign object, embrace and absorb and sometimes digest it.

Phagocytosis.—The process of absorption and digestion in white blood cells is called phagocytosis, and was discovered last century. About eighty years ago, Haeckel noticed that white cells of a mollusc picked up particles of indigo which he had injected into the tissues of the mollusc; and a few years later, Cohnheim and others discovered that the blood cells had sometimes microbes in their interior, and had the power of passing through the vessel wall and of wandering over the body. Finally, Metchnikoff made his famous bacterial researches. He began his investigations by inserting rose-prickles into the transparent larvæ of starfish, and discovered that the white cells of the larvæ quickly

mobilised and soon surrounded the prickles. Strange thing, is it not, that the prickles of a rose in the larvæ of a starfish should be the instrument and agents of a great scientific revelation! Nextly, the great biologist inoculated a small Crustacean—the Daphnia—with spores of a fungus and found that the white blood cells devoured the spores. Finally, he proved that the white blood cells devoured and digested the microbes of anthrax and other diseases. As Lord Lister remarked: "If there ever has been a romantic chapter in the history of pathology it is the history of phagocytosis."

The white blood cells, then, are essentially the army and navy of the body; they patrol the tissues and the blood, guarding them against hostile invasion; but they are also scavengers and remove from the blood such substances as indigo particles and catgut sutures. They act, too, as sculptors and masons, arranging and rearranging lime in the process of bone-making, and they devour the tails of tadpoles when the tadpoles change into a frog. As a rule they are useful, but in old age they may become destructive, and may devour the pigment of the hair and turn the hair grey, or devour the lime of the bones and render the bones brittle.

The white cells have a roving commission in the blood; they are individualists and outside the control and jurisdiction of the nervous system. How then do they know what to eat, and how to co-operate in their work, and where to mobilise? As we shall see, they

are not alone in the blood; they are in the midst of countless millions of red blood cells and blood platelets, yet they never eat these. But let a single foreign cell intrude and they usually detect it at once, pounce on it, and eat it. What is it that rules and regulates the conduct of these tiny organisms?

The white cells are attracted by certain chemical substances and are repelled by others. If fine open tubes containing various solutions are introduced into the body of an animal, the white cells crowd into some of them and scrupulously avoid others. This attraction and repulsion is called *chemiotaxis*, and the behaviour of the white cells in cases of phagocytosis, etc., is considered a kind of chemical reaction. But the behaviour of white cells even in the simple matter of phagocytosis cannot be entirely explained by reference to chemical reactions.

Nevertheless, phagocytosis, like all vital phenomena, certainly has its chemical side, and some years ago Sir Almroth Wright showed that there were substances—"opsonins" he called them—in the blood which, like appetising sauces, render the microbes more or less palatable to the white blood cells. If microbes and white blood cells are put into a certain blood serum (the fluid part of the blood from which the blood cells and other solids have been separated) each phagocyte will eat on the average, let us say, two microbes, whereas if the same microbes and blood cells are put into another serum each blood cell will eat on the average four or six microbes. Plainly, the serum supplies some kind

of appetising sauce, and it is quite possible that the white cells not only like the sauce but themselves play a part in making it.

It is a strange thing that the blood should be swarming with the white blood cells, in a way so independent of the body and yet so useful to it. They were certainly not in the Pre-Cambrian brine. How and when did they get into the blood? In the embryo they appear as modified cells in the middle layer, or "mesoderm," of the embryonic tissues, and they creep through the walls of the embryonic blood-vessels and become marine animals. In adult life they are formed in the bone marrow, in the spleen, and in the lymphatic glands. Their number is enormous. A healthy man shows about 8000 cells in each cubic millimetre of blood, and a temporary increase above that number frequently occurs. After food the white cells increase in numbers, and in bacterial infections and inflammatory diseases, such as septicæmia, pneumonia, and typhoid, they may multiply exceedingly and reach 150,000 to a cubic millimetre. The increase in many cases is only temporary, and under such circumstances it is good, for, as we have said, these cells are the soldiers, policemen, scavengers of the body, and up to a certain point the more of them the better. It may be mentioned in this connection that during the King's recent illness an increase in the number of his white blood cells was regarded as a favourable sign. Marvellous, indeed, it is that the marrow of the bones, the spleen, and the lymphatic glands should know to

produce more white cells to cope with sudden emergencies.

But not all increases in the number of white cells are temporary and advantageous. Sometimes there occur permanent increases due to disease of the blood or of the cell-producing organs. In the deadly and mysterious disease called "leucocythæmia" or "leukæmia"—due probably to disease of the marrow bones—the white blood cells multiply with extraordinary rapidity, and may reach the number of 1,000,000 in a cubic millimetre of blood.

The swarms of white blood cells then are important members of the commonwealth of the body.

THE RED CELLS.—Besides these white cells there are found in the blood other cells yellowish in colour—the red blood cells. These it is which give the blood its red colour. They are smaller than the white blood cells and measure only $\frac{1}{3200}$ of an inch in diameter; but they are much more numerous, and in a healthy man 5,000,000 can be counted in a cubic millimetre. They are round, flat, lens-like cells and have a thin wall around them so that they do not change shape and crawl about like the white cells. Their evolutionary history is obscure. Red cells are found in all mammals, and in birds, reptiles, amphibians, and fishes, but they are found only in rare groups of the animals lower than these. In the pond snail, in a few worms, and in the larva of a certain midge, and in a few marine worms there is a pigment similar to the pigment in the red blood cells; but no insects have red cells, and, talking

generally, the red cells are peculiar to mammals. It is a red pigment called "hæmoglobin" which gives the red cells their colour, and this pigment is of immense importance, for it is the carrier of oxygen from the lungs and gills and other respiratory organs to the cells of the body providing them with much more oxygen than could be carried in simple solution by the blood. Chemically speaking, hæmoglobin is so complex that its precise constitution is not known; but it has a characteristic absorption spectrum by which it can be readily identified. When light is passed through it, it absorbs all the rays except red and yellow (hence its red colour) and, moreover, absorbs some of the yellow rays, so that two black bands appear in the yellow part of the spectrum.

In view of the importance of hæmoglobin as oxygen carrier, it might seem strange that so few of the lower animals should possess the pigment. But quite recently Dr. Keilin, of Cambridge, has studied the absorption spectrum of transparent sections of animal tissues and has demonstrated that the absorption spectrum, whether of potato, or human muscle, or insect muscle, or yeast paste, always shows black lines in the yellow spectrum indicating the presence of some substance (named by him "cytochrome") akin to chlorocruorin and hæmoglobin. So that even those lower animals which lack red blood have yet in their tissues a precursor and representative of hæmoglobin called cytochrome—which (as can be proved) picks up oxygen and hands it on to the living tissues. Dr. Keilin has shown, moreover,

the interesting fact that the cytochrome is most abundant just where oxidation is most active. Thus the amazingly active wing muscles of certain insects contain more cytochrome than any other living tissue.

Hæmoglobin, accordingly, is one of the fundamental and essential constituents of living tissues, and its beginnings are to be discerned even in such lowly organisms as yeast—another fact that indicates how complicated and intricate are even the most elementary living tissues.

Hæmoglobin is the only living substance that contains iron, and to the iron it contains it owes its red colour; "Is it not strange," asks Ruskin, "to find this stern and strong metal mingled so delicately in our human life that we cannot even blush without its help?" *En passant* we may note that it is to iron that we owe many of the colours of the world, not only blushes, but orange, and umber, and russet soils, and the tints of agates, and jasper, and cornelians, and onyxes, and cairngorms, and marble, and porphyry, and granite, and tiles. Chlorophyll, the colouring matter of plants, also owes its colour to iron, and had Nature forgotten to put a little iron on her palette, it would have been a very dull and drab world indeed. It would also have been a dead world, for without chlorophyll and hæmoglobin life could not be. It is, as we have already mentioned, the chlorophyll of the plant that enables the leaves with the aid of the sun to break down carbon dioxide and build up the carbohydrates which are the foundation of animal energy,

while it is the oxygen carried by the hæmoglobin or cytochrome that renders the energy available. The hæmoglobin and the chlorophyll work together at the loom, weaving red and green into the wonderful woof of life, or to use another metaphor, the tiny red blood cells are the vestal virgins of the vital flames.

There are, as we have said, about five million of the little hæmoglobin specialists, the red blood cells, in each cubic millimetre of blood. Cells so small are almost all surface, and the total surface presented by the human blood cells is surprisingly large. It has been calculated that the total surface represents an area of more than 6600 square yards—more than three thousand times the area of the surface of the body. It has also been calculated that the superficies of the red cells would form a pavement more than two feet wide and more than twelve miles long, or a red tape half an inch wide and 280 miles long; while arranged single file, shoulder to shoulder, the cells would stretch more than 200,000 miles—more than two-thirds of the way to the moon. If all the red blood cells of all the men in the world were laid out as a kind of red tesselated pavement they would pave the whole surface of the globe.

The blood capillaries of the body stretch for many thousands of miles: those of the lung alone would extend from Liverpool to New York; and those of the muscles alone would go two and a half times round the equator; yet the red blood cells fill them.

These figures give us some idea of the numbers and infinitesimal size of the red blood cells. But the average

life of each cell is only a fortnight, so that the birth-rate must be prodigious, and the writer has calculated that in a lifetime of threescore years and ten enough red cells are produced to stretch about 400,000,000 miles, or more than four times to the sun—a distance which an express train going 60 miles an hour would require about eight hundred years to cover! It is almost incredible, but life is full of incredible things. Could slight variations ever produce torrents like that? Could they alter cataracts of life like that? When I discover facts like these, and when Darwinians talk of the efficiency of slight variations, I am reminded of the fable of the fly on the wheel.

Now the red cells do not grow and multiply in the blood: in the blood they seem moribund and dead. Where, then, do all the baby red cells come from? They are formed like many of the white cells in the marrow of the bones, where their birth and growth can be watched. They begin as little round nucleated cells and as they grow older they lose their nuclei. After a short life they break up, mostly in the liver which uses their pigmentary iron to colour its bile green or yellow.

All life long these swarms of tiny discs rush along the arteries and veins and carry oxygen to every cell in the body. If there are too few red cells or if the wonderful pigment hæmoglobin is deficient, a man becomes pale and loses energy and is short of breath. A rosy complexion means health just because it indicates that there are plenty red cells to carry the oxygen from the lungs to all parts of the body. In anæmic women there

may be only two-thirds of the normal number of red cells, and only 30 per cent. of the normal quantity of hæmoglobin; and in the dreadful disease called "pernicious anæmia" nine-tenths of the red cells may be destroyed.

Besides red blood cells and white blood cells there are also, as we have said, blood platelets in the blood. These are little granules much smaller than the blood cells, and their uses are not exactly known, but they seem to play a part in the coagulation of the blood.

The coagulation of the blood is one of its most useful and essential properties; for if blood did not coagulate animals would bleed to death even after a trifling injury. There are, indeed, some unfortunate people called "bleeders" whose blood fails to coagulate, and they live in constant danger of bleeding to death—a cut finger, the extraction of a tooth, may cause fatal hæmorrhage.

But even yet we have not half-exhausted the wonders and the mysteries of the blood. It contains not only sea-salts, and white cells, and red cells, and blood-platelets and coagulatory ferment, and opsonin, it also forms anti-toxins, which neutralise various poisons, and "agglutinins," and "precipitins," and "lysons," which slay or dissolve foreign cells, and particles, such as microbes.

One of the best known of the anti-toxins is the anti-toxin formed to neutralise the toxin of diphtheria. It is particularly interesting, for it led us to the discovery of treatment by anti-toxins.

If small quantities of the toxin of diphtheria are injected at intervals into an animal's blood, the blood forms more and more anti-toxin against the poison, and the animal becomes more resistant to the disease, or even immume. The anti-toxin, moreover, remains in the blood, even after the disease is conquered, and Von Behring discovered that if a small quantity of the blood, thus enriched with anti-toxin, is injected into an animal deficient in anti-toxin, it will confer on the animal a certain amount of immunity to diphtheria. This discovery is now put to practical use. By injecting the diphtheria toxin into horses their blood is enriched with anti-toxin, and thereafter a little of the horse serum is injected into the blood of those suffering from diphtheria, and serves to cure or modify the disease. In this way many thousands of lives have been saved. On the same principle other diseases can be treated and have been treated by serums containing anti-toxins.

When the blood forms an anti-toxin to combat a toxin, it forms a toxin available only for the special anti-toxin in question. It is surely an amazing thing that the blood should hit upon the precise chemical substance required to combat a disease it may never have met before.

In a similar mysterious and amazing way the blood forms substances to meet with other unforeseen emergencies, such as foreign particles, or cells. It not only attacks the toxins of microbes, it attacks the microbes themselves, forming substances such as "lysins" to

dissolve them, and "precipitins" to precipitate them, and "agglutinins" to stick them together.

If, for instance, a rabbit be given several injection of horse serum, its serum forms considerable quantities of precipitin, which forms a visible precipitate with the horse serum, and protects the blood against a dose of horse serum otherwise fatal. As in other instances of precipitation, the precipitin will precipitate perfectly only horse serum and no other serum.

But if foreign blood from an animal (such as a mule or donkey) nearly related to the horse is added, a small amount of precipitate will be produced. In this way, accordingly, efforts have been made to decide the relationship of various species and the relationship between man and the great apes; and it has been found that, according to this test, the Old World Apes are more nearly related to man than are the New World Apes.

When foreign blood cells are introduced into the blood of any animal, they are agglutinated by the blood agglutinins and destroyed; so that it is not possible to add red blood cells of one animal to the blood of another; and in cases of transfusion in man only human blood can be used.

In connection with transfusion a most extraordinary thing was discovered a few years ago. It was found that the blood of some men behaved to the blood of other men as if it were foreign, and that men, indeed, could be divided into four groups possessing four different varieties of blood. So that to-day before trans-

fusion is performed, the blood of both parties must be tested.

The four varieties of blood are heritable under certain laws, and thus it is sometimes possible to prove in a disputed case who is father of a child, and in America and Germany legal questions of parentage have been decided by blood-tests. What is the exact evolutionary meaning of these four blood groups is not known; but one group is more plentiful in Western Europe, and another more plentiful in Asia, while a third group is more plentiful among American Indians. The varieties therefore would seem to point to different racial origins, and they may possibly be correlated with many other intellectual and physical differences. It was an extraordinary discovery, and it opens up a large field for investigation.

Such then is mammalian blood—a crimson fluid derived from the ancient ocean—a crimson fluid swarming with millions and millions of microscopic cells, all performing essential functions in the life of the animal—a crimson fluid able to produce marvellous chemical substances competent to destroy invading germs and poisons—a crimson fluid carrying, moreover, oxygen and food to the cells of the body, and removing waste products otherwise fatal to them. Certainly it is the most wonderful fluid in the world.

And yet, were it a stagnant fluid it would be wasted. Its value depends on the fact that it flows unceasingly, carrying not only food and oxygen to the tissues, but removing from them carbon dioxide and waste products.

On this flow as we well know life depends, for if it ceases even for a few minutes we become unconscious and die. Even in such a simple organism as the amœba the fluid in it that represents blood is kept in constant motion. It was not sufficient to make a network of tubes all over the body: it was necessary also to contrive machinery to keep the blood in the tubes in constant circulation. That required an audacious ingenuity. But the multicellular organisms found ways of achieving it. The most elementary hearts were merely contractile bulbs, like the india-rubber bulb of a scent-spray, afterwards, double-pouched and treble-pouched hearts were invented, and finally, the four-pouched heart of the higher mammals.

The heart of man is a pear-shaped bag of muscles weighing about eight ounces and about the size of a clenched fist. By a transverse partition the bag is divided into upper and lower halves, and by perpendicular partitions these halves are again bisected. The upper two pouches form what are called right and left auricles, the lower two pouches the right and left ventricles. The right auricle and right ventricle communicate with each other by means of a valved orifice, and the left auricle and left ventricle also communicate with each other by means of a valved orifice; but right and left auricles have no inter-communication, and right and left ventricles have also no inter-communication. In fact the heart is divided so as to make two two-pouched self-contained hearts, a right and a left.

The most powerful propelling pouch is the left ven-

tricle, which receives from the left auricle blood oxidised in the lungs and drives it strongly through the great artery called the aorta which issues from it. From the aorta a number of large arteries spring, and two—the carotid and the jugular which branch off near its beginning—carry a big supply of blood to the brain. As the arteries extend through the body they divide into branches that grow ever smaller and smaller till finally they end in a fine network of microscopic tubes, the capillaries, which are closely applied to the cells of the tissues and have such thin walls that they allow of an interchange of gases and fluids between the cells and the blood. It is through the capillary network that the blood gives up its oxygen and food to the cells, and it is also through the capillary network that the cells put waste products and carbon dioxide into the blood, so that the blood, which reaches the cells as crimson arterial blood, leaves them as blue venous blood.

In its further course, the network of capillaries joins into tiny veins, and the tiny veins join into larger ones, and finally two large veins, the "superior" and "inferior venæ cavæ," open into the right venous auricle, and thus a circuit is made all round the cells of the body from the left ventricle to the right auricle. All round this great circuit, through dozens of large arteries, through thousands of little arteries, through tens of thousands of capillaries, the powerful left ventricle drives the blood, beat after beat. In this arduous work it is assisted by the muscular and elastic fibres which surround the arteries. By these fibres not only is the

flow assisted, but it is kept steady between the beats, as the flow through the nozzle of a scent-spray is kept steady between the grips by the elasticity of the bulb and elastic tube. Were it not for the musculo-elastic bands round the blood-vessels the blood would flow not smoothly but in jerks. The work of the left ventricle is also assisted by valves in the veins which support the blood as it rises towards the heart, by the compression of contracting muscles and by the pull of the expanding chest.

We have followed the blood, then, in its circuit from left ventricle to right auricle, but the right side of the heart has no direct communication with the left side. How, then, does the blood get from the right auricle back to the left ventricle ? The route it takes is short and well-chosen. The right auricle contracts and drives the blood into the right ventricle, and the right ventricle grips the blood and drives it through the pulmonary artery into and through the capillaries of lung into the pulmonary veins which open into the left auricle, and the left auricle promptly passes the blood into the left ventricle, which expands to receive it. In its passage through the lung, the blood is assisted by the up and down respiratory movements of the chest wall. The course of the blood, therefore, is from left ventricle round the body to right auricle, from right auricle to right ventricle, from right ventricle through the lungs to the left auricle, and from the left auricle to the left ventricle. The auricles and ventricles are timed so as to work harmoniously together in their work of pro-

pulsion. In the course of its journey from left ventricle to right auricle the blood passes through the great organ the liver, where many chemical changes are effected, and where some of the glucose received from the digestive organs is stored for after-use ; some of it also passes through the kidneys, where water and some salts and impurities are abstracted from it. Again, in its course from right ventricle to left auricle, all the blood as it passes through the lungs is freed from excess of carbon dioxide, and the hæmoglobin of its red-blood corpuscles which has lost its oxygen and its bright red colour picks up oxygen and again becomes the bright red " oxyhæmoglobin " which gives the blood in the arteries its vivid colour. So that the blood is not merely propelled with its cargo of food to the cells, but is purified and oxidised *en route.* The processes of respiration whereby the blood loses its excess of carbon dioxide and takes up a fresh supply of oxygen are beautifully co-ordinated with the circulation ; and the construction of the lungs and whole respiratory system to fit their functions and facilitate gaseous interchange is a miracle of device. Where more oxygen is needed heart and lungs co-operate to procure it. But unfortunately in these few pages there is no time fully to discuss respiration. We can merely draw attention to the fact that not only lungs, and heart, and atmosphere all work together, but that they work in collusion with every other organ and cell in the body. We see in the body a microcosm in a macrocosm knit together in small as well as in large relationships.

The action of the valves in directing the flow of the blood is, of course, of great importance.

We cannot here give a full description of all the valves that regulate the currents of the blood and allow of flow only in one direction, but it may be mentioned here that there is a valve between the left ventricle and the aorta that allows outward flow from the heart, but closes and resists backward flow when the left ventricle begins to expand, at which moment its closure can be heard as a click. Also between the right ventricle and the pulmonary artery there is a valve which allows the blood to be driven forward into the lungs by the contraction of the ventricle, but which closes and allows no backward flow into the ventricle when the pouch dilates to receive the blood from the right auricle. Further, between the left auricle and the left ventricle and the right auricle and the right ventricle there are valves which permit flow only in one direction, from auricle to ventricle.

It was partly a consideration of the valves that led Harvey to the discovery of the circulation of the blood, and now that we know all about their action it may seem strange that the discovery was so belated. But it really required some courage to push the valves to their logical conclusion, for though to-day familiarity has divested the blood flow of its marvel, it is still difficult to believe at first that it is possible. I remember quite well that when I was told, as a small boy, that the blood circulated right round the body through every inch of it, I looked at my fingers and took the

information with a few grains of salt. For to make the blood *circulate* through every inch of the body and reach even the fingers and toes, requires not only a powerful and perfect force pump, but an almost incredibly well-arranged vascular system. And, indeed, when Harvey first published his discovery, he was considered crack-brained and lost most of his practice.

Man's heart weighs only about eight ounces, yet its power is tremendous. An active man can raise himself 2000 feet in an hour, but the heart does work equivalent to raising itself 6000 feet in an hour, or about thirty times to the top of Ben Nevis daily. Put otherwise, it raises every twenty-four hours 32 tons, or 144,600 times its own weight a foot high, or in a lifetime of seventy years it generates enough force to fling itself to the moon and back again. For more than a hundred years it may beat without a rest, save the pause before it tightens and grips the blood, and even in the embryo, before there are brains and lungs, it still beats beats away. "A little bloody point like the point of a pin, glowing like a red star in a cloud, blossoming and fading away, that is how the proud heart of man begins, but no movement in the universe, not even the whirling of a sun or the burgeoning of a nebula, is so wonderful as the throbbing of the tiny red beadlet, for it is the beginning of the activities of life."

Each grip of the human heart drives forth about 4½ ounces of blood, so that in a day it pumps out about 2700 gallons, and in a year about a million gallons, and on the average each drop of blood circulates back to

the heart in 45 seconds. On the average, too, a drop of blood flows about a mile a day, or 365 miles a year, or 25,000 miles in a lifetime of seventy years. But a drop of blood is very unlikely to take the same route twice, for the capillaries are a labyrinthine network, whose meshes measure in aggregate thousands of miles—the capillaries of the lung alone would reach from London to New York.

The rate and force of the heart's beat is regulated by nerves—the vagus nerves curb it, the sympathetic nerves spur it—but it is not nerves that initiate its beats and keep it beating. Before there is any nervous system, when the heart is only a tiny red bead, it begins to beat of its own accord, and it continues to beat of its own accord by virtue of rhythmic discharges of its own solar energy. It is incorrigible in its beat: it beats on after it has been cut out of the body provided only suitable fluid food, such as an oxygenated warm solution of salt and sugar, is driven through it; and Alexis Carrel, the French-American surgeon, has shown that even a strip of heart-muscle cut out of the heart will keep beating, or at least contracting, for months if it is properly fed. It is, of course, the energy in the food that moves the muscles, it is plainly a chemico-physical reaction; but nevertheless the co-ordination of the energy on the body is not chemico-physical. The mainspring of a watch is physical, but its relations to the wheels, and the wheels' relations to each other, are something more than physical.

For seventy or eighty or ninety or a hundred years,

day and night, the heart of man grips on. No hand could grip so strongly, so skilfully too—for it has to adapt its grip to changing circumstances—but it never tires. Thinking of that, I have sometimes thought what a pity it is that our voluntary muscles are not equally strong and tireless. But, after all, that would require many awkward and undesirable alterations in the body, for the heart in order to work so hard and ceaselessly would require proportionate amounts of food and oxygen, and if all our muscles were to emulate the heart we should require a stomach about the size of a beer-barrel, and lungs about the size of balloons.

The beating heart is a thing unique, and when we think of millions and millions of vertebrates, whales, and herrings, and lions, and crocodiles, and mice, and men—whose hearts never for a moment cease beating and driving the crimson fluid along, our imagination falters. Were all the hearts of all men united in one mighty heart driving the whole blood of humanity along, what a mighty crimson torrent it would be, a very Mississippi—a very Niagara of life!

CHAPTER IX

BONES AND MUSCLES

"And the narrowest hinge on my hand puts to scorn all machinery."—WALT WHITMAN.

VERTEBRATES, the most important of the two great divisions of the Animal Kingdom, owe their pre-eminence largely to the internal framework of lime—the bony skeleton to which their muscles are attached—and it is interesting to notice that the lime was collected and prepared for them during millions of years in most patient and ingenious ways.

One of the first experiments made by the primal unicellular animals was the protection of their soft protoplasm by shells of lime or glass. The sea in these days had in it merely the minerals corroded by acid water from the lava and basalt, and the proportion of lime in lava and basalt silicates being small the quantity of lime in the primal sea must have been small. But these unicellular animals were also very small—most of them microscopic—so in proportion to their bulk they were almost all surface for lime collection. Moreover, they moved in the sea, and the sea moved over them, and accordingly, one little microscopic cell might—so to speak—sieve lime out of tons and tons of sea water. We see something of the same kind to-day in some of

the tunicates which collect from the sea appreciable quantities of the very rare element vanadium, which occurs only in infinitesmal quantities.

The little lime-collectors lived and died in countless millions, and for millions of years before the advent of vertebrates their shells accumulated in the bottom of the sea, forming enormous masses of lime. On the bottom of the sea the lime seems useless, but nature has long, long thoughts—often plots millions of years ahead, and this lime on the bottom of the sea was a very deep-laid plot indeed.

For some millions of years the little sea creatures toiled away amassing lime : for millions of years Nature waited, and then, in the Tertiary Epoch, she gripped the earth in her strong hand, and the bottom of the great pre-historic Tethys Sea puckered and wrinkled, and the lime rose to the eagle skies as tremendous mountain ranges—the Alps, the Pyrenees, the Himalayas, etc. Then the sun lifted clouds, and the clouds condensed on the new mountain peaks, and torrents ran down the limestone slopes and dissolved the carbonate of lime so that the water became comparatively full of lime. Even yet it would have required a prophet to see what was going to happen ; but in time it did happen. Creatures not only swam in the water, but drank the water ; and the water, comparatively rich in lime, became available not only for making external shells but also for making internal skeletons. There was enough for both. The first animal that hit upon the bright idea of an internal skeleton was the embryo

of a tunicate; the tunicates therefore may be called, in a sense, the inventors of the vertebrates. But the idea was not patented, and the lancelets and sharks and other fishes improved upon the tunicates' invention and elaborated the ingenious jointed backbone that combined strength with flexibility, and that was not only an internal skeleton for the attachment of muscles but also an external case to protect the nervous system. The fashion became as popular as short skirts, the amphibians and reptiles and birds all adopted it, and when the mammals appeared they also followed suit. So the limework of the little foraminiferæ and the bigger nummulites was not wasted: they had been really working to make clouds and mountains and rivers, and so lime-water for the great family of vertebrates. A few thousand volcanoes, a few million years of lime collection, a cataclysm or two, a few ranges of lime mountains, a few million tons of clouds just to make a few bones. But that is how Nature works, and we point it out at such length here because there are crowds of people—the kind of people who talk about life on other planets, and Martians, and artificial cells, and artificial evolution—there are crowds of people who never seem to realise the cause behind cause in all the things of Nature, and the myriad-sided, multiplex, co-ordinated, integrating, far-sighted, colossal yet finicky labour which life has required in its every detail. Where life is concerned there is special truth in the phrase, "Parturiunt montes, ridiculus nascitur mus." ("The mountains are in labour, and a ridiculous mouse is brought forth.")

Man being a vertebrate has a bony skeleton, and a bony skeleton, strange to say, remarkably like the bony skeleton of apes; indeed, his bones look like modifications of the first bones invented by the first fishy bone-makers, and it would be very interesting to discuss man's bones from the point of view of comparative anatomy. But we must be contented here with a brief description of human osteology as it is.

The bones, like all other living tissues, are much more wonderful things than they seem at first sight. At first sight they seem simply rods and lumps of lime jointed together; but they are much more than that. Chemically speaking, they are made mostly of phosphate of lime, with quantities of carbonate of lime, fluoride of lime, phosphate of magnesium, and sodium chloride; but the salts are not simply moulded to the outward form of the bone, they are laid down in such structural ways as to make the bone light and elastic, and yet give it resistance to the special strains to which it is exposed. If we cut open a long bone, such as the upper arm-bone, or thigh bone, we find that there is a long canal running along the centre of the shaft and that the two ends have a honeycomb or sponge-like sort of structure. All the long bones have this spongy structure at their ends, and in the shorter cuboid ones, like the heel-bone, the same structure is found. The cylindrical shaft of long bones, on the other hand, is made of very dense and hard bone like ivory. Such construction shows engineering talent, for it economises material without sacrificing strength. The hollow shaft, like hollow

pillars, is just as strong for the weight it has to carry as a solid bone of the same calibre, and the spongy material in the short bones and in the heads of long bones is arranged in such a way as to give elasticity and so diminish jar and shock. Not only so, but the solid dense bone that makes the cylinder of the shaft is arranged in concentric layers, and the beams and arches and spokes in the short bones and in the heads of long bones are skilfully disposed to meet various kinds of strains and stresses. The spongy part of small roundish bones, for instance, like some of the bones of the hands and feet, is arranged, more or less, on the principle of a wheel with a central hub and radiating spokes, while in the neck of the thigh-bone layers of bone are arranged in decussating curves like Norman arches so as to sustain the weight transmitted to the neck from pressure on the head of the bone. And so in every case.

The strength of bones is still further increased by an animal substance called "collagen," which thoroughly permeates them. Collagen when boiled is converted into gelatine, and it is this substance that is extracted when we make soup out of bones. The animal matter is retained a long time in bones, and Gimbernat once made soup from a mastodon's tooth and Dr. Buckland made soup from the bones of a prehistoric hyæna.

If the mineral salts of bone are dissolved by acids, a soft pliable bone made of the collagen remains, while, if the collagen be removed by burning, the bone is rendered more brittle and less elastic. In their natural state bones are very elastic. The ribs can bend con-

siderably without breaking, and the Arab children make bows out of camels' ribs. Even the bones of the skull are elastic, and a skull thrown on a hard surface will bounce, as some of us who have had croppers on the ice may have noticed.

The manner in which bones are made is very extraordinary, and makes one realise that life is something more than a matter of chemical reactions, and that there are processes which cannot be explained by survival of the fittest.

The skull-bones are prefigured in membrane, but all the other bones are prefigured in cartilage, and in both membrane and cartilage the bone is built up by microscopic cells of the same type as the white corpuscles of the blood or the amœbæ of the ditch. These little masons and plasterers and hodmen are called "osteoblasts" and "osteoclasts," and carry out their work in a most capable way, creeping and crawling here and there, and laying down lime salts just where salts ought to be. One of the most remarkable things about their work is that they have not only to build but to demolish, for the cartilage contains cells called cartilage cells, and for some reason the cartilage cells start building bone. But the cartilage cells do not make a good job of it, they simply lay down lime anyhow in a quite irregular unscientific way, without making a central canal, and without considering strains and stresses, and eventually they wall themselves up in the lime, and die of inanition. When the osteoblasts and osteoclasts, accordingly, appear on the scene, they realise that the lime is badly

laid down and the first thing to be done is to remove it, and this the osteoclasts quickly do, and as they remove it the osteoblasts lay down new bone skilfully arranged in arches, and buttresses, and laminæ. A very extraordinary thing is the fact that these bone-builders work by time-table, starting different bones at different definite dates and different parts of the same bone also at different dates. In the thigh-bone, bone is laid down at the lower end of the bone a fortnight before birth, but not at the upper end till the child is a year old, and the various bony sections are not united into one solid bone till the twenty-first year.

Another extraordinary thing is that millions of the builders are built alive into little spaces in the bone, but food reaches them, and they do not die of inanition like their predecessors—the cartilage cells.

When the bone is finished it is a very elaborate and complicated structure indeed. Not only is the lime laid down with such architectural and engineering skill, but it is inhabited by millions of encloistered cells ; and arteries, and veins, and lymphatics, and nerves run in all directions through it. More than two hundred small arteries enter the lower end of a thigh bone.

The building of bones by millions of independent free cells has always seemed to me one of the great mysteries of life. What teaches them to co-operate, each doing infinitesimal bits of a general complicated scheme? Certainly none of them ever did it before, nor could each of them inherit skill to do any particular job in any particular place, for there are millions and millions of

such cells all wandering "through the ither." They are not co-ordinated by a nervous system; they have no nervous connections. There is no architect, no master builder, no foreman, and yet they build as if to specification.

When the human bones are finished they closely resemble, as we have said, the bones of an ape, and evolutionists explain the similarity by genetic descent, but the bones of both men and apes are made by free crawling cells, and how could genetic descent possibly account for their co-operative osteological performances? The fact that I am descended from an ape would hardly teach my osteoblasts to make my bones or any bones: osteoblasts make the bones because some power not themselves guides them, and when any of them die others take their place. Whatever explanation there may be for the making of bones by osteoblasts or of the likeness between bones of animals of various species the very manner of their making proves that genetic connection and mechanical causology can have nothing to do with it. The osteoblasts are born of other osteoblasts that never had made bone in the whole course of their existence.

The osteoblasts and osteoclasts, moreover, not only can make bones, but can remake them, and genetic descent hardly, I think, explains that, for they may be called upon to remake many bones, some of which may not have required remaking in the course of many generations of the vertebrate. If a bone be broken the osteoblasts proceed to mend it, and if it be badly set they lay

the lime in such a way as to enable it to resist stress and strain in new directions. Even if a big bit of bone be destroyed the osteoblasts can restore it if only the membrane covering the bone—the periosteum—is left. Once when Dr. Joseph Bell, an Edinburgh surgeon, was going his round in the Edinburgh hospital, a young man walked into the ward. "I have that man's thigh-bone in my surgical collection," he said. The thigh-bone had been diseased and Dr. Bell had removed it, and the osteoblasts had thereupon constructed a new one.

Compared with other materials, bone is very strong—twice as strong as oak and nearly three times as strong as ash. The strength of spongy bone tissue is especially remarkable. A cubic inch of spongy bone weighing only fifty-four grains was taken from the lower end of the thigh-bone and put in the position it occupied in the living body, and it was found that in that position it would support a weight of 400 pounds without giving way, and strong men have been known to carry even heavier weights.

In certain diseases and under certain nutritional conditions, however, bone may be imperfectly made or may be destroyed after being built up. In rickets, for instance, the bones lack lime, and are soft and misshapen, chiefly owing to deficiency of a vitamin—vitamin D—in the food, and in this connection a very interesting fact was discovered that this special vitamin may be formed in the skin by the action of certain ultra-violet rays, so that deficiency of it in food may

be made up for by supplies from the skin. That is an interesting and instructive fact, but far too much has been made of it. In a disease called "osteomalacia," which attacks adults, the lime is absorbed from the bones so that they soften and bend, and sometimes break. A story is told of a man who was able to pack his wife, who suffered from this form of bone-softening, into a portmanteau, and thus escape paying railway fare for her. In yet another disease called "acromegaly," full-grown bones of the adult, especially the bones of the face and hands and feet, start growing again, and cause considerable deformity. The overgrowth is due to disease of a gland called the pituitary, a little gland the size of a bean which lies at the base of the brain, and secrets some substance which influences bone-making. Disease or over-activity of this gland is probably also the cause of giantism, and some people have suggested that by a diet of extract of pituitary a race of giants might be created. People who suggest that kind of thing lack scientific instinct, and do not seem to have noticed the extremely intricated correlated chemistry of the multicellular living organism—where we certainly cannot touch a flower without troubling of a star, and where a single flaw in the lute will make all music mute. There are in this world both minnows and whales, midges and mammoths, and size is not simply a matter of a pituitary gland, nor, as Frederick the Great discovered, is it merely a matter of selection. Size, like all other qualities, is a wheel or a system of wheels among wheels and wheels.

There are in the human skeleton five hundred and twenty bones of all shapes and sizes—no less than twenty-two in the skull and no less than twenty-four in the hand. Together they weigh only about twenty pounds, and the popular idea that it is bone that weighs is therefore erroneous. They are all jointed together to make the skeleton. Some, like the bones of the skull, are dovetailed together so as to be practically immovable, others like the ribs swing about. The hip-joint is a ball-and-socket joint, the ulna-humerus joint is a hinge joint, the axis-atlas is a pivot joint. Unless dovetailed together the bones that make a joint are held together by collars and bands of strong fibrous tissue, the ends of joint bones are covered with thin cushions of cartilage or gristle, and between their opposed ends is a loose bag filled with lubricating fluid so that there is no friction when the joint bones move.

The uses of the bones are manifold. They give rigidity to the animal. Without vertebræ we should be a kind of mollusc or worm. They protect the vital organs. The heart and brain unprotected by bones would soon be destroyed. The ribs act as the frame of a bellows, the orbital bones make a socket for the eye, the turbinal bones make a scaffolding for mucous membrane; while these connected with the limbs, thorax, abdomen, neck, jaws, give attachment to muscles and give the muscles mechanical advantages which without bones they would not possess. It is the bones and joints that make walking and writing possible, and bones, joints, and muscles are most admirably

adapted for the purposes which they serve—and adapted, there seems reason to believe, by providence. How many muscles, and nerves, and brain-cells, and spinal cord cells take part when a brilliant pianist plays a piano I do not know; but it is perhaps the most complex co-ordinated nervo-muscular movement that man performs, and it is difficult to see how any possible process of variation and selection could have led to such miraculous efficiency, as all the movements and the whole muscle-nerve-brain complex are far removed from the movements and complexes that are of survival value, and, further, may appear in men and women with no heredity experience of such performances.

We cannot properly discuss bones without discussing muscles, nor muscles without discussing bones, for in most cases they work as one.

Most of the muscles are attached to bones and in many cases move them. In a man of average size they weigh about sixty pounds, so that of muscle nearly half the body is built, and on muscle and fat its whole contour depends. And while a bare skeleton gives us feelings of horror, a skeleton covered with flesh gives us a sense of beauty, provided the lines follow certain curves. Behind the sense of beauty is admiration, often subconscious, of health, and strength, and efficiency; and the musculo-osseous lines that normal men and women admire in men are just such lines as indicate these qualities. No doubt, the attraction of what we call bodily beauty is a device of Nature to assure healthy matrimonial selection, and in so far as racial

standards of beauty vary, in so far also are there probably different hygienic requirements. Black is the colour of beauty among black races, probably just because pigment in the skin is required in tropical countries to protect the tissues against ultra-violet light; and the cult of stoutness that is all right in flat countries like Egypt or Holland and that proves vigorous digestion, could not prevail in the mountains of Scotland or Switzerland where fat would impair climbing efficiency. We admire the swelling biceps and deltoid muscle of a Hercules, and find them beautiful because they suggest vigour and vitality, just as we admire regular white teeth and straight nose, and a good chin and bright clear eyes, because these traits indicate vitality and health and energy.

The standard of beauty, of osseo-muscular beauty, in women is not the same as in men, just because each sex has its own special health requirements. A man, as respiratory functions prove, is made for muscular work, and in a man, therefore, large firm muscles are a beauty and desirable. A normal woman has to spend a considerable portion of her most active years in child-bearing, where big muscles—unless perhaps abdominal and diaphragmatic—could not be used and would be simply a burden to the heart and nutrition, hence down all the centuries the ideal feminine form has had softly rounded muscles. Again, as child-bearing and lactation make certain demands on the nutritional reserve of a mother, a certain plumpness, a certain amount of sub-cutaneous fat, has always up to a few years ago, at least,

been among the criteria of feminine beauty, and in the same way breast curves indicating suckling capacity have always had æsthetic value.

Here I should like to say a word on the vagaries of modern standards. For some years now, for various reasons, in Western countries, and especially in England, it has become fashionable for women to undergo what is called physical training and dietetic treatment in an endeavour to get rid of their curves and of their subcutaneous fat, and in an endeavour to develop the musculature of a man or rather of a weakly boy. In this endeavour they have been encouraged by ignorant writers in the press, and, I regret to say, even by doctors. The craze had probably a double origin. On the one hand, it arose because certain leaders of fashion lacked healthy feminine lines, and clothes and fashions and figures had to adapt themselves to the leaders. On the other hand, it has been more or less necessitated by a life of constant muscular movement led by most modern women. Women are not naturally made for such persistent muscular activities: most of them have neither the muscular strength nor the respiratory capacity, and they found that they could keep up the pace only by reducing their weight like jockeys, and so made a sort of fashionable cult of skinniness.

It has been a totally unhealthy movement: it has violated the laws of Nature: the laws of beauty and the laws of health—and every sensible man and woman with a love of health and beauty, and with a recognition of the racial value of sex attractions and distinctions,

must rejoice to see signs that the craze is on the wane.

The decadence in art is also part and parcel of the same departure from healthy standards. The muscles of the human hand in their lines have beauty for us because they represent lines of health and efficiency, the lines that have enabled man to be more than ape. The muscles of the face have beauty because they express health of body and vitality of mind, and when a decadent like Epstein produces a Rima with a dislocated shoulder, and a hand apparently affected with rheumatoid arthritis—when he produces a Night with the face contours of a degenerate, he is making a mock of beauty, of the sound healthy instincts of the normal man: he is blaspheming health and beauty: he is blaspheming the Maker.

From the æsthetic point of view, the muscles, and especially the human muscles, are very important things, and it may be remarked that Greek sculpture was at its highest when the Greek intellect was doing its best work.

Leaving these general considerations, let us look at muscles more from the scientific standpoint.

Physiologically speaking, there are two great classes of muscles: the voluntary—such as the muscles of the hand, which are usually under the control of the will—and the involuntary—such as the muscles of the heart and arteries, that are quite apart from the will.

The voluntary muscles, as we know, occur in bundles, and bands, and sheets; but when we analyse them we

find that they are built up of little fibres each of about an inch long. Each of these fibres is only about $\frac{1}{500}$th of an inch in diameter, so that even a tiny muscle may contain thousands of them, and a large muscle like the biceps half a million of them. Capillaries and lymphatics run between the fibres, and each fibre, remarkable to relate, has its own nerve fibrils—a motor nerve and a nerve of sensation—and each fibre is quite separate from its neighbours. When we examine one of the fibres of a voluntary muscle we find it has a cross-striated appearance as if made up of microscopic white and black draughts pieces stuck together, but nevertheless it can be split up into still finer fibres. There is little doubt, however, that a muscle is semi-fluid in consistence.

The involuntary muscles have spindle-shaped fibres only $\frac{1}{600}$th of an inch long; they are connected with each other by intercommunicating arms of their substance and they show no cross-striation. The fibres can contract like the heart without any stimulation from a nerve, but nevertheless each involuntary fibre has two nerves, one to increase its contractile activity, the other to decrease. The muscles of the heart are anomalous in that though they are involuntary muscles they yet show faint striation. As already mentioned, they also, like the other involuntary muscles, have accelerating and restraining nerves.

The voluntary muscles, as we know, are all attached to bones, and their contractility is used to move the bones or to compress or propel the contents of sacs and

cavities such as the air-vessels of the lungs, and the bladder. The involuntary muscles, on the other hand, have no bony attachments, and usually are applied to hollow viscus in the shape of hoops and rings. It is involuntary muscles, too, that adapt the lens of the eye to distance and that contract the iris. The voluntary muscles act much more quickly than the involuntary.

The most characteristic physiological feature of a muscle is, of course, its contractility, and from birth to death every muscle is more or less in a state of contractile activity. At all times we are having a certain amount of muscular exercise. Even at rest some of the fibres of every muscle, even of voluntary muscles, are kept in a state of contraction by little twitches that we do not see or feel, but which can be recorded by delicate recording instruments, and which can be heard through a stethoscope. Sometimes even without a stethoscope they can be heard, for the low booming sound we sometimes hear when we lay our ear on a pillow is the sound of the little contractions of the masseter muscle which moves the jaw and whose upper attachments are near the ear. When we feel limp and slack it often means that these involuntary contractions are feeble, and the bracing tonic effect of a cold bath or a dose of strychnine is largely due to a strengthening of these unconscious movements.

The bigger contractions of muscles are just exaggerations of these never-ceasing little ones—simply an extension of the contraction to more fibres.

When by an electric discharge we cause a human

voluntary muscle to twitch, we find that each twitch requires $\frac{1}{10}$th of a second, preparations to contract take $\frac{1}{400}$th of a second, the contraction takes $\frac{4}{100}$ths, and relaxation requires $\frac{5}{100}$ths. We cannot produce twitches more quickly than that in a human muscle, and if we stimulate a muscle more rapidly than once each tenth of a second, the stimulations do not produce twitches, they produce a chronic contraction. The actual effective contractions of the muscles are built up in this way by forty or fifty or more nerve discharge and muscle twitches a second. Since we take $\frac{1}{10}$th of a second over each twitch, it is plain that we cannot make more than 600 movements a minute. In this respect many birds and insects can beat us. A fly can make 335 vibrations per second with its wings, and bees can almost manage 500 per second. On the other hand, a frog's muscles cannot manage to outpace a man's, and the muscles of a tortoise can reach no more than 60 twitches a minute.

The normal twitches and contractions are excited by discharges from motor-nerve cells, but the muscle has contractility in itself, and can be made to contract after its nerves are killed.

A curious thing about the contraction of muscle fibres is that, whatever fibres contract, they contract to the full extent of their capacity, and the difference between a weak and a powerful contraction of a muscle is not a question of individual fibres contracting more strongly, it is merely a matter of more fibres being engaged in the contraction. The strongest and longest

contraction a muscle can make is the sum of the contractile force of all its fibres contracting at once.

The contractile force of muscles is very great. A piece of muscle weighing only 15 grains can lift a weight of 60 grains to a height of 13 feet, and consume in the work less than a thousandth part of its substance. While, according to Professor A. V. Hill, the biceps and brachialis anticus of a fairly muscular man can exercise a force of 2000 lbs., though they weigh only one-half to three-quarters of a pound.

Muscle is the most economical power machine we know, since there is more energy available in it for work and less wasted in heat than in any other engine. Nor bulk for bulk can the work performed by high explosives compare with the work performed by men's own muscular tissues. In a lifetime of seventy years a man's heart generates enough energy to fling itself 2,000,000 miles. Many a man in thirty years of work does muscular work with his voluntary muscles equal to lifting a ton two thousand times to a height of 4000 ft., and a strong man in a fortnight can produce as much force by muscular contractions as concentrated in one explosion would fling a 1-lb. weight about 2000 miles high. The total potential energy of the men slain in the Great War must have been millions of times greater than the energy of the explosives that slew them, and if we consider that in the loins of millions of the dead were potentialities of life that might have gone energising for millions of years, we have some idea of the tragic waste of energy that war implies.

In voluntary actions not single muscles but groups of muscles act and act in co-ordinated co-operation, and this has always seemed to me one of the most astonishing things about volition. There are five hundred and twenty muscles in the body, and the combinations required to perform most actions must be very complex. About three hundred muscles each do their bit to balance a standing man; and if a man run or walk, hundreds of muscles have constantly to adjust themselves to every movement, and have constantly to alter their part in the action. In any complicated motion whatsoever such as writing, or walking, or hopping, or speaking, many muscles must work together with precision, aiding or balancing each other, momently altering their individual action, and we do not even know what muscles are acting or how they are acting, yet we will to walk, or run, or write, and the muscles at once do what we wish. We say we *learn* to walk or to write, but we only learn in the rough—we learn to will that certain definite general movements should take place, but the greater part of the actual play of the muscles is automatic from the first, and we ourselves could never be clever enough to pull the strings to call into action all the nerves and muscles required. We may be able to drive coaches and four in our body, but not coaches and fifty. Moreover, no muscle group works by itself. If I stand on tiptoe the muscles of my loins and dozens of other muscles have to participate in the action, and even the muscles of the heart and the muscles of the blood-vessels have to do their quotum.

We never separately control our muscles and co-ordinate them, their varying co-ordinated contractions are arranged by discharges from motor cells in the cerebrum and cerebellum and spinal cord, and these discharges are largely regulated by various nerves which are variously stimulated by the movement of fluid in the semicircular canals of the inner ear. We have nothing to do with these discharges, we are not aware of the movement of the fluid. It is all arranged for us: we *will* and the action is carried out. It is as if we had a typewriter able to spell words and coherent rational sentences at the push of single keys. This mysterious action of the will is one of the facts that most clearly show the mysterious connections between mind and body, and that show, too, the existence of machinery in the body which cannot be explained by chemistry, and which could not have been perfected by any selection of chance variations. I may pick letters by chance out of a bag and in time spell a word or two; but I cannot do a sum in integral calculus by chance, nor could these complex co-ordinated combinations on which we ring the changes in playing music and in other actions be the product of casual variations and selection.

Man has become Lord of the Animal World not through muscular strength, but through these mysterious subconscious muscular co-ordinations obeying the suggestions of his will; and the little muscles of the thumb have done more to exalt him than his most powerful muscles; while the chief use of his most powerful muscle, the extensor muscles of his thigh, may be said

to be the maintenance of an erect posture, so that the fingers and thumbs, free from the locomotion duties, can co-operate in more intellectual co-ordinations.

Probably nothing less than millions and millions of cells and fibres cunningly related in the brain and spinal cord would suffice to make the muscles efficient agents of the will and in the intricate delicate instrument in its relation to the mysterious will we seem to see prescient and infinite Wisdom at work.

Now let us look at the source of energy in the muscles. Mysterious as may be the directions and co-ordinations of the muscular activities the energy is chemical and is derived, as we have pointed out in other chapters, from the thermal energy of the sun transmuted in plant cells into chemical energy and supplied to animals in the form of foods. The amount of energy thus supplied can be realised and measured by burning, that is to say by oxidising the food, and the food of the muscles is, as we have said in a previous chapter, the sugar glucose carried to them by the blood, but though the energy of the food may be measured by combustion, the energy production in the body is more than a process of simple combustion.

Up till quite recently it was believed that the oxygen borne along by the red corpuscles of the blood combined with the glycogen to form an unstable explosive material called "inogen," and the act of muscular contraction was supposed to be initiated or caused by an explosion of this material. But a few years ago, a new theory was proposed by Sir Walter Fletcher and Professor F. G.

Hopkins, and this theory has superseded the inogen theory. As a result of very careful experiments, Sir Walter Fletcher and Professor Hopkins came to the conclusion that the glycogen is not built up into an explosive by means of oxygen, but is itself an explosive, and that it is its explosive energy that is transformed into the molecular movement and heat of muscular contraction.

But the new theory has its difficulty to face. We explode petrol by a spark, but what makes the glucose explode ? Glucose is a pretty stable substance. We do not find that chocolates which contain glucose are dangerous bombs or that the glycogen ever blows up its tank—the liver. What makes glucose explode ? Well, the fact of the matter is we do not yet know ; but there is certain evidence which suggests that impulses from the motor nerves set free in the muscles certain chemical substances, "enzymes," and that these enzymes act on the glucose as a spark on petrol. It seems possible, too, that other ferments from the thyroid, pituitary, supra-renal, and pancreas gland also act as minor sparks.

When the glucose explodes it breaks up into carbon-dioxide and lactic acid, and it is believed that the energy of the explosion acts chemically through the chemical action of the lactic acid, for lactic acid applied to a muscle causes contraction. Professor A. V. Hill, who is the greatest authority to-day on muscles, has suggested that the lactic acid acts by robbing the protein molecules of the muscles of their sodium and

potassium salts, so altering their electrical quality that they attract other elements of the muscle and thus cause contraction. If Professor Hill be right we have in muscular contraction an electrical phenomenon.

But though contraction is an explosive and not combustive matter, yet, as our hard and deep breathing during muscular action shows, there must be oxidation and combustion mixed up in it somewhere. The heart beats stronger, the respiration is quicker and deeper, everything goes to indicate that oxygen is needed and used. What is the oxygen needed for and used for? Sir Walter Fletcher demonstrated that it is used to burn up excess of lactic acid in the blood, and at the same time to build up part of the same excess into glucose. Lactic acid, as we have said, stimulates muscular contraction but in *excess* it causes muscle fatigue and even muscle death, and the oxygen burns up a certain amount of the excess lactic acid, turning it into water and carbon dioxide, and at the same time with the energy acquired by the combustion reconstructs a small quantity of the lactic acid into glucose. The carbon dioxide thrown into the blood by the explosion is not wasted, it is a stimulant of the respiratory centres, and so keeps the lungs acting vigorously. The whole process is, indeed, one of the beautiful, ingenious, complicated, co-ordinated arrangements which we find everywhere in the body, and which compel all really scientific minds to postulate a rational Maker.

As we have said, lactic acid in excess causes muscle-fatigue and even muscle death. In moderate exercise

it is kept within limits by the oxygen supplied by respiration, and by the alkaline salts in the blood, but there is a point when it accumulates faster than it can be neutralised or oxidised, and that means impairment of muscular power, fatigue, and perhaps breakdown, and until the excess of lactic acid is completely removed the muscle cannot act with full power. During rest, after excessive exercise the oxidation of the lactic acid goes on steadily, and in five to eighty minutes all the lactic acid is turned into carbon dioxide, water, and glucose, all the engines have been cleaned out and fresh petrol put in the petrol tank.

In the normal heart it is interesting to note, lactic acid never accumulates, probably because the heart-muscles are well supplied with blood almost direct from the lungs, and so are rich in oxygen. The heart, it may be mentioned, pumps into its own walls no less than five pints of blood every minute. That is a wise provision of Nature, for if lactic acid *did* accumulate in the cardiac muscles there would be danger of heart failure. The feeling of general fatigue which follows violent exercise is probably due to lactic acid dispersed through the body by the circulation, but this dispersed lactic acid is soon removed and not only is it removed, but a certain amount of the new glucose formed from it goes to muscles all over the body so that they benefit by the labours of the overworked local muscles.

The modern theory of muscular energy is thus exceedingly interesting. The energy in glucose—energy originally imparted by the sun—is set in action by a

ferment which explodes the glucose breaking it into lactic acid and carbon dioxide, and the solar energy thus evoked is changed in some way into the energy of muscular contraction. The contractile energy of the muscle is really the energy produced by the jerking or clashing of electrons in the sun 93,000,000 miles away, and every time the eye winks one can say with scientific accuracy "twinkle, twinkle, little star." Another instance of the far-reaching threads of the woof of life—another instance of the complexity of vital relations.

It is strange to think that every man doing muscular work is producing sour acid out of sweet sugar—forming drams of the same acid that is formed in sour milk; it is strange too, to think that the acid of sour milk moved the chisel of a Phidias and the pen of a Milton, and moved them too, by causing thousands of co-ordinated little explosions. But can anyone really imagine that chemical explosions and electric re-arrangements undirected by a mind produced Phidias' sculptures or Milton's poetry? *I* certainly cannot. The five hundred million little grey cells in the brain that handle like artillery officers the millions of batteries in the muscles are sometimes at least directed by a human mind, and the grey cells and the batteries could never be capable of such magnificent marksmanship if an Infinite Mind had not made them on purpose.

We may conceive of man as millions of microscopic maxims never ceasing in their fire, as millions and millions of microscopic shells that burst day and night in every brain-cell in every eyelash; but when we look

at the complexity of the explosive mechanism, when we see the sunbeams in the lyddite of life, when we watch the accuracy of the gunnery practice we cannot fail to recognise that guns, the munitions, were all made in the Arsenal of God.

CHAPTER X

MAN AND EVOLUTION

"From floating elements in chaos hurled,
Self-form'd of atoms, sprang the infant world,
No great First Cause inspired the happy plot,
But all was matter and no matter what."

HORACE SMITH.

"The assumption of a monophyletic evolution of the whole kingdom of organic life is a delightful dream without any scientific support."—WASMANN.

"It is impossible for scientists longer to agree with Darwin's theory of the origin of species."—W. BATESON.

WITH incorrigible curiosity the mind of man has always analysed and dissected the world of concrete experience; and to-day, as we have seen, it has reduced matter to invisible particles; but underlying and perhaps unconsciously inspiring this instinct to analyse into fundamentals has always been a craving, conscious or unconscious, to find fundamental unity. Man has analysed in order to synthesise: he has picked to pieces in order to unify; he has tried to discover in "the boundless inward of the atom the boundless outward of the whole," and perhaps all the time he has been really hoping and groping for the integrating Spirit in Whom all things live and move and have their being. "Behold I make all things whole!"

From the days of Thales and Democritus—from the

days when thinkers first began to think, we find that the human mind picked matter to pieces not to remould it to the heart's desire, but rather to reveal identity in difference. We find that the early thinkers not only had some inkling of a unifying *prima materies*, but even of the mud and blood relationships of all living things. Yet only last century did the analyses of chemistry and comparative anatomy lead men to a full and consistent theory of inorganic and organic evolution. That theory, magnificent in its scope, fearless in its audacity, weaving together nebula and amœba, amœba and man, seemed to give to the whole cosmos a new coherency and new dynamic significance, and revealed to the imagination of science and poetry, and—may I say theology—the moving fingers of the Maker. Every cold dead crater became as genial-pregnant as a womb, and worms crawled out mysteriously of stars and become sons of God.

It was a colossal conception, at once an evangel and a prophecy, and it has had worthy evangelists and prophets—Darwin, Huxley, Spencer, J. A. Thomson, Haeckel, Ray Lankester.

Seen in its fullest scope, Evolution starts from much the same starting-point as Epicurus and Lucretius: it starts with invisible electric particles roaming in the icy darkness of ethereal space, and it conducts us through æons of fiery turmoil to a planetary system and Man.

In some mysterious way the electrical charges—for so far as I know variation and selection has never been applied to the evolution of atoms—so it is held—grouped

themselves into ninety-two or more of the amazing miniature solar systems we call atoms, where each extra electron in the systems had such momentous consequences as we now summarise in such names as oxygen, hydrogen, carbon, nitrogen, phosphorus, radium, gold. These atoms thus mysteriously formed were the foundation of the universe as we know it, and in presupposing the formed atoms we presuppose a great deal. Evolution starting with atoms and atomic affinities puts several rabbits into the hat before producing them. However, let that pass.

Under the grip of the mysterious power we call gravitation, the cold, lonely atoms—as isolated at first as the stars in the sky—closed together and aggregated, and segregated, while the collisions of their crowding electrons caused greater and greater heat till the atoms became not only aggregations of atoms, but blazing suns wherein much of the aggregation changed, as already described, into radiations of light and heat.

All that was mysterious and wonderful; but evolution had then no life in its scheme. That came about, as we have said, through a cataclysm—through a cataclysm that tore a great sun and converted it into a spiral nebula in whose arm condensed the world—twice cooked like a biscuit. Accident or not accident, Nature at this point seems here again to have made no experiments in casual variations, but to have gone straight to her goal of life. She produced a planet straight away with just the right elements in its crust to make protoplasm, with just enough explosiveness in

it to make steam and gases in the proportions required. She made the planet also—strange to relate—of just the right size to retain the steam and gases, and she sent it whirling round a central sun just at the right distance, so that the heat of the sun could lift clouds and make rivers and mud, and energise food for the organisms to come. There does not seem to have been much "hit or miss" in these processes—rather they seem like a prescient concatenation of factors preparing for life. And they led, so say the evolutionists, to chemical compounds which not only exhibited the vital properties we see in unicellular organisms to-day, but contained in them such evolutionary chemical potentialities that, under the influence of environment, they grew *seriatim* into all the flowers, and birds, and beasts, and men, and books, we know to-day, just as inevitably and blindly as carbon hydrogen grows into formaldehyde —grew by anoetic chemical reaction.

The common theory is that the first cell formed by anoetic chemical processes varied more or less by chance in various directions, that the variations were transmitted and related, and that in time the bigger complex variations which separate species were created and fixed.

One of the simplest and first of evolutionary variations must have been cellular *proliferative coherence*, and whether Nature foresaw its consequences or not it certainly proved a most successful and most important and most progressive variation, for the mere numerical difference between a microbe and a mammoth is

immense. The microbe has one cell, the mammoth perhaps a hundred million million, so that even if we suppose that variation always added cells and never subtracted them—even so it would have required millions of years to bridge the mere quantitative numerical gap.

Among the first multicellular organisms were the sponges, which appeared millions and millions of years before baths and bathrooms. They consisted of cells arranged in such a way that currents of water could pass in through microscopic pores and pass out again through a larger opening. The current was kept in circulation by cells provided each with a little whip in constant motion, and from microscopical particles in the flowing current the cells extracted their nourishment. The food came to the cells and they did not require to hunt for food, so all the sponges were fixed to some object in the water. To hold the cells together there was a skeleton made either of fibres as seen in the common bath-sponge, or of spicules of lime or silica. There was nothing like a common digestive cavity or nervous system or respiratory organs or heart, and the only obviously differentiated cells were the cells with little whips or flagella. A simpler form of multicellular organism it would be difficult to conceive.

But Nature soon perceived that if she were going to mass together myriads of cells some new way of feeding them must be contrived, for massed together they got in each other's way like too many pigs at a small trough. So she made the cœlenterates, putting cells together to make a doubled-layered bag like a sponge bag, and

round the mouth of the bag arranging tentacles to grasp food carried past them. Not only so, she put in the arms thread-cells—cells with the power of throwing out fine hollow barbed filaments containing poison strong enough to paralyse small animals, even to inflict injury on a man. So that if some soft creature like an insect's larva got within reach of these arms it was soon as full of arrows as a St. Sebastian. Both the arms and the bag were contractile, and the cells composing them might be regarded as primitive muscular tissue, and usually there were nerves.

Some of the cœlenterates, like the sea-anemones, are fixed and do not move, others like the jelly-fish are free and swim about by contractions of the body sac. In size some are microscopic, some eight feet across, and about half a ton in weight.

Cœlenterates grow by budding and often the buds are connected. Coral is the lime skeleton of a species of budding and branching cœlenterate.

Sponges and cœlenterates obviously had their points, and displayed amazing originality and ingenuity, but they certainly gave no hint of the higher animals that were to evolve out of them, and it was left—so say the evolutionists—for worms to lay the foundations of the vertebrata, even the groundwork of man. Why at this point the germplasm should show such a crop of momentous and providential innovations evolutionists do not explain. The radial symmetry, of the cœlenterates was given up, and a bilateral symmetry, that has persisted till to-day, substituted in its place. The

germplasm, further, instead of dividing so as to arrange a double layer of cells, divided so as to form a triple layer of cells which is the basis of all the higher animals up to Man.

The lowest form of worm, the flat-worm, invented a central system with a brain of sorts, and also an intestine; but it had neither circulatory nor respiratory system, and distributed its food merely by means of a much branched gut, and absorbed its oxygen through its surface.

These were great advances, and the round-worms, the Nemertine worms, and the Annelid worms took further steps and invented a body-cavity, a blood system, hæmoglobin, and feet of sorts. So that hundreds of millions of years before the coming of man most of his organs were prefigured in the worms.

They certainly were extraordinarily lucky variations that not only initiated and achieved, but also co-ordinated, all these new organs, and also it was an extraordinarily lucky variation that hit upon that most complicated substance, cytochrome or hæmoglobin, and that put it into blood-vessels and made it intermediary between the atmosphere and the tissues. It is difficult to understand how any one can fail to see Mind behind luck of that kind.

After the worms came the Arthropods, which are supposed to have sprung from the sea-worms. By surrounding their soft bodies with a hard case of a substance called "chitin" the arthropods protected their vital organs, and at the same time provided attachments for

muscles and so for the movements of wings and legs. In the arthropods, accordingly, legs and wings came to be of great importance as we see when we look at such members of the group as lobsters, crabs, fleas, spiders, dragon-flies, bees. Legs and wings, too, led in most cases to a land life, and the land insects are the most numerous and most varied of all the organisms. The wings were, of course, quite a new invention, and quite a new invention was the respiratory system, in the form of a network of air tubes penetrating the body in all directions, and quite new inventions, too, were feelers and jaw developments. The heart remained simple, for the blood had to carry only food, and not, as in the case of higher animals, oxygen; but the nervous system became greatly developed, as can be seen by all the precise actions of insects and other members of the order. The eyes of the arthropoda are of an extremely elaborate kind, consisting each of many little eyes all set in a bunch—each eye with its own retina. Some dragon-flies have no less than 25,000 little eyes in each big compound eye, and they seem to have had just the same complicated eyes when millions of years ago they flew in the Silurian forests.

Arthropods have not only sense of sight, but sense of touch, and taste, and smell, and sometimes of hearing. It is also possible that they have an electric sense, and that, as Ladowsky has suggested, they are able to send wireless waves to each other.

The instincts of insects, as is well known, are extraordinary. The spider's web, the organised life of an

anthill or beehive, are among the wonders of the world. It may be noticed *en passant* here that a mosquito, the anopheles, which appeared hundreds of millions of years before man, has slain millions of men by injecting into their blood a microbe created millions of years before itself. That will give us some idea of the incomprehensible workings of Providence.

Having made some hundreds of thousands of different arthropods, varying from lobsters to butterflies, scorpions, ants, bees, and mosquitoes, one might have thought that variation had reached its climax; but at about the same point in the varying germplasm where the arthropods began, began also the Molluscs, which, going on quite other paths than the insects, outstripped them in some ways.

Most molluscs have shells, and most of them live in water—among them may be mentioned oysters, snails, periwinkles, octopuses. An octopus may reach a huge size and measure more than thirty feet between the tips of two extended arms, and it has an eye quite comparable to the eye of a vertebrate with retina, sclerotic, choroid, vitreous humour, aqueous humour, and an adjustable lens. It is surely a very amazing thing that a great grotesque creature like an octopus should be blessed with such a wonderful instrument as an eye. Not only has the octopus an eye, it has also jaws like an eagle's beak, and when the beak has seized food a digestive juice is pumped over it and dissolves and partly digests it, and the octopus sucks in peptonised soup, as it were.

Also about the same point as the insects and molluscs began the brachiopods—the lamp-shells, and the echinoderms—star-fish, sea-urchins, sea-lilies, etc. These are curious unprogressive phyla and we need not describe them here, and must proceed now to the higher phylum of the Chordates or Vertebrates.

The invention of a flexible cylinder to protect nerves does not seem in itself a very big step forward, yet its consequences were tremendous: it at once made possible a light limy skeleton enabling the muscles to perform efficient and complicated actions such as had up to that date been impossible. A jelly-fish may weigh a ton, an octopus may have arms two yards long; but neither can ever have the activity or applied strength of an ape. The backbone acted as a *point d'appui* for the muscles and opened up quite new possibilities of muscular action. But further, its expansion into the cranium offered opportunity for a development of the brain such as no invertebrate had ever enjoyed.

Probably the first animal to encase its dorsal nerves was a tunicate: the case was not strictly speaking a backbone, it was not made of rings of bones merely of fibro-cartilage, and to-day the adult tunicates do not show it, and we only believe that they possessed it because it appears transitorily in their larva. To-day the most primitive chordate extant is the amphioxus, which has a nerve-cord running along its back, but neither limbs, nor bones, nor heart, nor head. There is nothing impressive about it at all, but, nevertheless, the eggs and sperm that escape through its body-wall were

in process of varying toward the vertebrate soma, and the next vertebrate we find, the lamprey, shows a great advance in that direction, for it has a well-developed brain, and a nose, and ears, and eyes, as well as a vertebrate heart and liver, and rudimentary thyroid. Bones and teeth appeared first in the fishes, which, as is well known, have a bony backbone and plenty bones, and possess jaws and teeth.

According to evolutionists some of the great fish family gave origin to the amphibians, which were the first land vertebrates, and in the Carboniferous period flourished and attained a considerable size. To the amphibians succeeded the reptiles, which lorded the Earth till the end of the Secondary period and developed in some cases to enormous sizes. The herbivorous dinosaur, called the diplodocus, grew to be a hundred feet long, and the carnivorous tyrannosaurus stood twenty feet high. It looked at one time as if the reptiles were to oust all other animals from the world ; but suddenly they died out, leaving to-day only such forms as lizards and serpents. Why they died out is a mystery. Possibly climate had something to do with it. Possibly famine may have put an end to them. Anyhow, in the Tertiary period they had to make way to the birds and mammals.

Between a reptile and a bird there are a good many big differences which would seem to require remarkable variations to bridge, but evolutionists think that the archeopteryx that lived about the middle of the Secondary period was an intermediate form. But it was a

good deal more bird than reptile, for it had feathers and wings.

The adaptation of the bird to its life is one of the marvels of evolution. The feathers are each of them delicately and intricately and ingeniously made; and the bones are hollow and can be filled with warm air to give lightness. Not only is the bird anatomically adapted for flight, but the automatic machinery in the nervous system must be beautifully contrived to work the wings in flight. Any erroneous variation on the road to perfection would have ended that line of evolution, for a bird that crashes is a dead bird. Beautiful, however, as birds are, and great aviators as they are, they have never developed brains, not even so much as the insects on which so many of them feed.

But the reptile had more powerful descendants than the birds, for it is believed by most evolutionists that reptilian germplasm developed into the mammals which are the dominant animals in the world to-day, and which have ended by producing brains far surpassing the brains of reptiles and birds.

The character, however, that distinguishes mammals as a class is not brains, but milk glands; all the females have milk glands and suckle their young. With the exception, too, of the duck-bill platypus and echidna which lay eggs, all the mammals have placentæ, so that the embryo is fed by the mother's blood till it reaches the stage when it can be suckled.

In activity the mammals far surpass the reptiles, and one mammal, the whale, is larger than even the largest

reptile of the Secondary period. Some of them, such as the horse, have undergone great variation or rather mutation since their first appearance; and in many cases, as in the dog, pig, rhinoceros, and hippopotamus, the brain seems to have grown progressively larger. Even to-day great variations and mutations in mammals frequently occur, and these are taken advantage of by man for breeding purposes. The angora goat, the ancona ram, and most of the fancy breeds of dogs have been bred in this way.

To arrange the various mammals *seriatim* according to their genetic relations, and to the date of their appearance, would be extremely difficult; but it is certain that the family to which man is supposed to belong is the most recent, and that man himself is one of the most recently established species of the family, and probably has not been in existence for much more than 500,000 years—though Osborne says perhaps for 3,000,000 years.

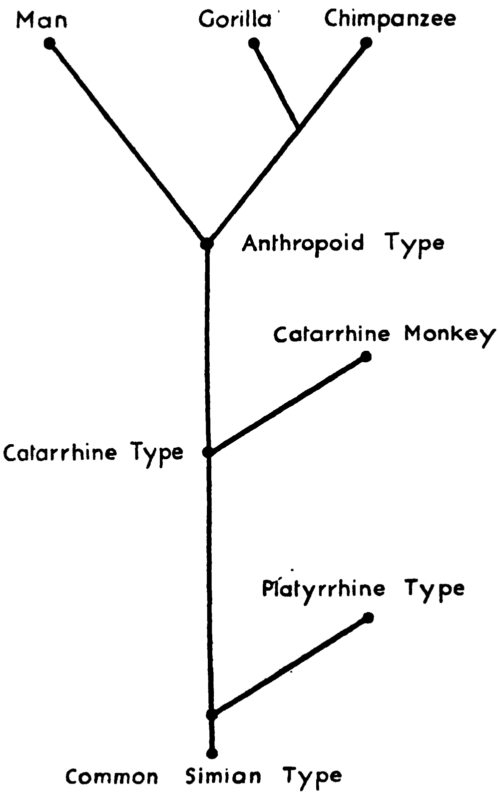
According to Haeckel, evolution ran the following course: (1) Green cells; (2) Amœbæ; (3) Sponges; (4) Anemones; (5) Worms; (6) Amphioxus; (7) Fishes; (8) Amphibians; (9) Reptiles; (10) Monotremes; (11) Marsupials; (12) Insectivoræ; (13) Primates.

Almost all evolutionists believe that Man belongs to the Order Primates, and includes among his direct collateral kin Old and New World monkeys, the gorilla, the chimpanzee, the orang, the lemurs, and the tarsius, but opinions as to his exact lineage vary very widely.

Darwin believed that from a common Simian type

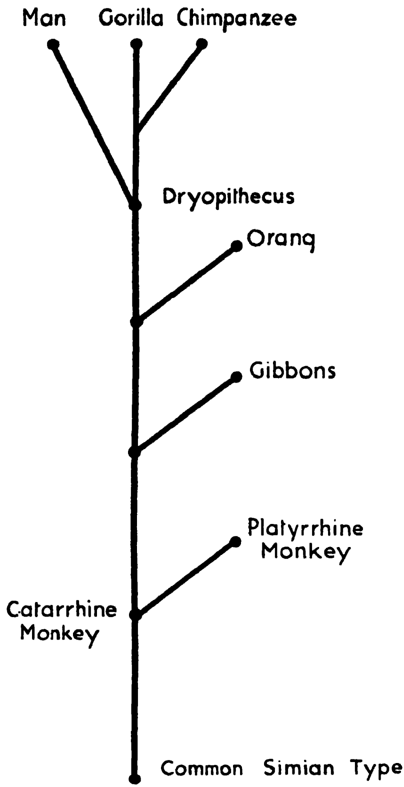
there branched off the Platyrrhine monkeys of the New World and the Catarrhine monkeys of the Old World, and that Man, the gorilla, and the chimpanzee are branches of the Old World monkey, so that a recent ancestor of man was a kind of monkey which lived in the trees, and had a tail.

DARWIN'S TREE OF LIFE



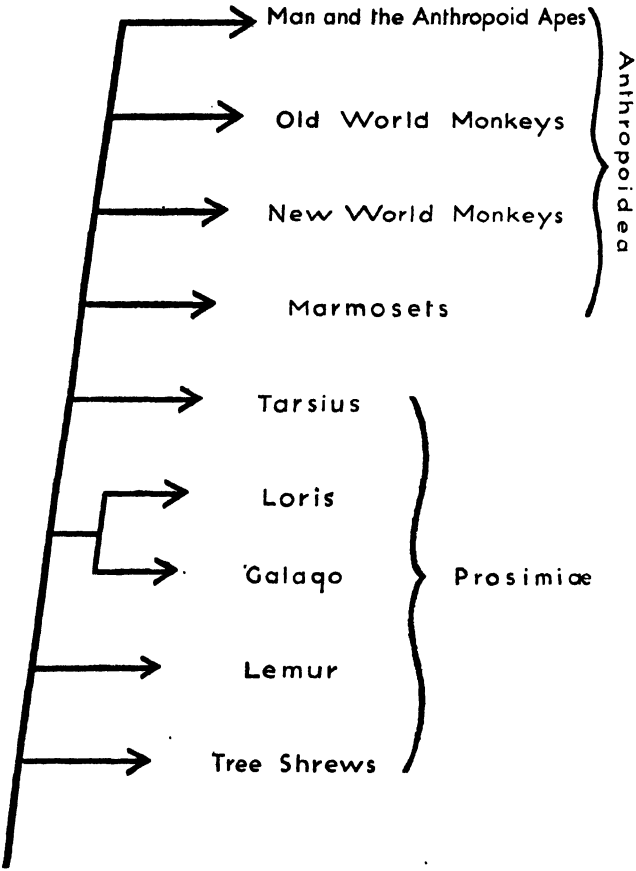
Haeckel also traced Man directly from the Catarrhine and Platyrrhine monkeys, and put orangs and gibbons as our direct ancestors.

HAECKEL'S TREE OF LIFE



So, according to Haeckel, Man's direct ancestors included not only a kind of monkey, but also a kind of gibbon and a kind of orang.

In *From Monkey to Man*, L. H. Dudley Buxton gives the following tree :



W. K. Gregory and Elliot Smith agree in a general way with these pedigrees, and W. K. Gregory maintains that after twenty years of investigation he has been

"unable to discover a single valid objection to the direct evidence afforded by comparative anatomy, and in harmony with the palæontological record of the entire Primate Order so far as is known, namely, that man's relatively close kinship with the chimpanzee and the gorilla is an unassailable fact, that he is a member of a group that, so far as is known, first appears in the Oligocene Epoch, and is characterised originally by the erect position (as in gibbons), by the primitive branchiating arms, and by feet with divergent great toes, that of this group the existing anthropoids remaining in the ancestral forests became over-specialised in the direction of extreme branchiation; while the ancestors of man, left perhaps in a region of dwindling forests some millions of years ago, early in the Miocene Epoch, spent more and more time on the ground, with resultant changes in functions which have partly masked the still more ancient and deeply impressed arboreal stamp upon the brain and sense organs and locomotor skeleton."

"Man," he says, "belongs to an Order all the members of which were completely adapted to arboreal life as far back as the Lower Eocene. With surprisingly few exceptions, highly varied tree shrews, lemuroids, chairomyoids, tarsioids, New World monkeys, Old World monkeys, gibbons, and great apes are thoroughly arboreal even at the present day, and only a few, such as the baboons and certain other monkeys, have more or less given up arboreal life for life on the plains." He traces man from the Dryopithecus (a Primate like a

chimpanzee) of the Miocene Epoch through a tarsius, and holds that human characters emerged in the Pliocene.

Some view of that sort is held also by Sir Arthur Thomson and Sir Arthur Keith. It is at least a picturesque theory, and now that gorillas and the apes are usually placed as cousins and not as direct ancestors there is less reason for our pride to rebel. Indeed, in respect to gorilla and ape ancestry, Osborne says, "I regard the ape human theory as totally false and misleading. It should be banished from our speculations not on sentimental but on purely scientific grounds, and we should now resolutely set our faces towards the discovery of our actual pro-human ancestors."

According to monkey-ape-tarsius pedigrees we were at least always *arboreal* animals. We scrambled on the trees as lemurs and tarsi, until—so the theory supposes—scarcity of trees brought us down to the ground and we learned to walk erect and to use our hands in useful ways. The Propliopithecus—the earliest ape nearest our direct line, a near ancestor of all living apes, lived in Egypt, and as ancient man has been found, among other places, in South Africa and South America and Java and Australia and England, our forefathers in spite of their arboreal history must have become very remarkable pedestrians. Where our ancestors lived when they came down from the trees, or how they found food, and how they escaped from the big cats of the period, history does not relate. It is usually supposed that the most intelligent apes

came down from the trees, and that the difficulties and dangers of ground life further developed their intelligence; but it may be pointed out that the baboons which live on the ground are not more intelligent than the apes that live on trees, and it may be further suggested that in event of a shortage of trees the strongest and most intelligent apes would hang on and the weakest and stupidest would be pushed off. Nevertheless this theory of descent from the trees is commonly accepted, and the grasping power of a newborn baby's hand is supposed to be inheritance from ape or at least from arboreal ancestors millions of years ago, though the transmission so long to a baby of a grip so useless is hardly consistent with the Darwinian hypothesis of the survival of the fit:

> "Children, behold the chimpanzee,
> He sits on the ancestral tree,
> From which we sprang in ages gone.
> I'm glad we sprang, had we held on
> We might for aught that I can say
> Be horrid chimpanzees to-day."
>
> O. HARFORD.

There are, however, some great authorities who do not believe that man had an arboreal history. Professor H. F. Osborne, for instance, who is a very great authority, makes the following most interesting and heretical statement:

"Even at that vastly distant date" (the Pliocene period, 3,000,000 years ago) "the ancestors of the horses, asses, zebras, were but little different from their modern descendants. So far as is known, the Pliocene men were essentially like the men of to-day except in

minor points; especially is this true apparently in the essentially human characters of the brain and mind."

As a result of long studies he concludes that:

"1. The human family, like other families, includes a great number of independently evolving phyla, which for untold ages evolved independently of each other in different parts of the world.

"2. As in other mammals, we shall very rarely find the true stem forms at the bottom of the phyletic lines.

"3. The older of these human phyletic lines may well run back as far as do other lines of mammals, that is at least to the Lower Oligocene or Eocene. Hence, even in these inconceivably remote ages, we may expect to find Dawn-men—erect-walking, plains-living, large-brained, speaking men, totally dissociated from the family of apes, especially in their evolutionary trend which was toward life in the open, while that of the apes was toward more and more specialised life in the trees.

"4. Hence the idea of man's ape ancestry is a myth and a bogy due to our previous ignorance of the real course of human evolution. For millions of years man has been a ground-living, erect-walking being, and if at some earlier period he may have passed through an *arboreal* stage, such a stage could not have been long, or have left a very deep imprint upon his skeleton and nervous system."

According to Osborne, then, it is very doubtful whether we ever lived in trees and passed through a monkey stage.

Klaatsch, also a very great authority, is very much in agreement with some of these bold conclusions of Osborne. "Man's teeth," he says, "are remarkable as a survival of the original condition which was the starting-point of all the various types of mammal teeth. Thus man is extraordinarily primitive in regard to his teeth. They could not possibly have developed, for instance, from those of a lion or an ox; but it is certain that at some remote period the ancestors of the lion and the ox must have had teeth similar to those of man to-day.

"It follows that there can be no question whatever of the evolution of man from any existing type of mammal, and that he must have parted company from them at the very root of the family, like the other Primates which have teeth similar to his. On the evidence of the teeth, therefore, man's ancestors must be described as very ancient types in the geological sense."

Klaatsch further maintains that monkeys and apes are probably degenerated branches of the pro-human stock.

Another eminent authority, Wood-Jones, agrees with Klaatsch that the monkeys and apes are degenerate branches of the pro-human stem and that man never passed through a simian stage. He holds that man evolved from some tarsius-like creature, and that in the course of his evolution he never resembled an ape. "Hence," he says, "any so-called missing link would be very unlike the popular picture of a brutish, slouching

creature made more horrible than any gorilla by a dawning touch of humanity. This missing-link picture must be deleted from our minds, and I find no occupation less worthy of the science of anthropology than the not-unfashionable business of modelling, painting, or drawing these nightmare products of imagination and lending them in the process an utterly false value of apparent reality. The pro-human member of the human stock would probably be a small animal, and we would not venture on a nearer guess than that which any one is free to make as to the identity of an animal intermediate between a tarsius-like form and man."

Wood-Jones, then, though like Klaatsch and Osborne disbelieving in a simian stage of human development, does not find man's mammalian origin so far back as they do; but conjectures that it branched off as a separate branch from a tarsioid. This theory, whether right or wrong, of the direct origin of man from a tarsius-like creature is of great interest, for the tarsius was one of the first mammalians in which both eyes looked forward and were co-ordinated in conjoint vision—one of the first mammals, too, in which the eye and the visual centres of association took priority of the nose.

There is no doubt that, so far as the bones of the skull go, man's skull is much more primitive than the bones of the skull of the great apes, and much more like the skull of a tarsius or gibbon than the skull of a gorilla, and it is extremely unlikely that modern man once possessed an anthropoid cranium and afterwards lost it. The foot of the human embryo also supports

Wood-Jones' and Klaatsch's repudiation of an anthropoid stage in the evolution of man. Wood-Jones points out that as soon as the foot is formed in the embryo, it is "of the characteristic human type: at no stage is it a monkey's or an ape's foot." "The curvature," says G. S. Miller, "is at all stages essentially as in the human adult; no true approach to the structure characteristic of the apes is visible.

In view of the very different opinions expressed by such great authorities the whole question of the genetic relationships of Man must be considered open, and even those who believe in organic evolution can only suspend their judgment.

There would seem to be, at least, three evolutionary possibilities: either, as Wood-Jones maintains, we evolved from tree-shrews, lemurs, and tarsioids, but never passed through a monkey or ape stage; or we are direct descendant of some very ancient animal, antecedent not only to tree-shrews, lemurs, and tarsioids, but also to lions, and tigers, and horses, so that we never were even lemurs and tarsioids, far less monkeys and apes; or we were consecutively tree-shrews, lemurs, tarsioids, anthropoids, and Man—that Man, as Metchnikoff put it, is "a kind of miscarriage of an ape."

The last theory is commonly believed, and most people do not realise that it is in a very shaky condition. Indeed, ever since Huxley's debate with Bishop Wilberforce, a belief in the ape descent of man has been considered by the laity as logically unassailable and intellectually *de rigueur*, and most clergymen to-day

believe it at least as implicitly as they believe the Apostles' Creed, and would consider it an insult to their intelligence to question their scientific orthodoxy in the matter. So commonly is the ape-man theory believed that even in books of science for children we have the pictures, that Wood-Jones so rightly deprecates, of shaggy ape-like primitive Man.

If we are to believe in the genetic evolution of man from worms and sharks, there is no reason to be shocked at the discovery that we had apes among our forbears, but there are many reasons why we should not believe too readily in an unpleasant relationship that is very far from proven, and why we should spoil a child's imagination with ugly pictures which certainly do not suggest to him pride of ancestry or *noblesse oblige*:

> "Hold to the good: define it well
> For fear divine Philosophy
> Should push beyond her mark and be
> Procuress to the Lords of Hell."

When a great man of science like H. F. Osborne affirms that he regards the ape theory as a theory "totally false and misleading that should be banished from our speculations—our *speculations*, mark you—and our literature"—and that the "idea of man's ape ancestry is a myth and a bogy," it is time that the public learned that the theory of genetic evolution of man from a monkey, or from a collateral of a monkey, if not totally false and misleading, is at least a quite unproven hypothesis.

And the same thing is true of all the other hypo-

thetical genetic connections on which the theories of continuous genetic evolution is based.

As imaginative speculations the theories are to be welcomed, for they have at least intellectual beauty and intellectual audacity. The mind able to imagine the dust becoming alive and growing into an amœba, and the amœba growing into worms and whales and diplodoci, and monkeys, and men—so different from each other and yet so perfect in their kind—if not the mind of a scientist, is at least the mind of an epic poet blind as Homer; and the mind bold enough to try to account for these miraculous transformations by the Darwinian theory of environmental and matrimonial selection of casual variations, is, at least, a mind of magnificent courage and enterprise.

The Darwinian theory of life being carved out by love, and famine, and fire, and fang, and claw, has a great intellectual and imaginative appeal. What a miracle—what a magnificent miracle we view when we watch all life coming out of one tiny speck of magic dust. Think of it. The first little bit of procreative material—germplasm—budded bud after bud, for millions and millions of years, and each bud in the multicellular organisms brought forth a body—a soma varying slightly from the parent body which produced it. The variations were casual, some did not fit the environment and made for death, but some fitted and survived, and the germplasm of the fit variations brought forth somata like the parents, and simply by such casual variation and selection were produced starfish and

anemones, and worms, and crabs, and oysters, and cuttle-fish, and sharks, and atlantosauri, and iguanodons, and whales, and mammoths, and mites, and butterflies, and humming-birds, and horses, and hippopotami, and ant-eaters, and tarsi, and monkeys, and ape-men, and men — simply by casual variation and coincident selection were produced such amazing organs and combinations of organs as fins, and wings, and feet, and legs, and arms, and hands, and brains, and nervous system, and hearts, and blood-vessels, and liver, and lungs, and pancreas, and thyroid, and kidneys, and ovaries, and eye, and ear, and nose, and larnyx, and so forth. Variations in a worm produced lobster claws and a spider's web, and teeth, eyes, ears, nerves, and blood-vessels, and blood; variations in the tunicate produced a backbone, in the fish a camera eye, in the triton a five-fingered hand, in the duck-billed platypus and the spiny ant-eater mammary glands, and in marmosets and monkeys Shakespeare's plays and Newton's mathematics.

This Darwinian theory of genetic evolution postulates no God and no directive mind with purposive prescience, and so amazing is it that many might be inclined to quote:

> "Lest men suspect your tale untrue
> Keep probability in view."

Nevertheless, it was supported by Darwin with such a mass of evidence and by Spencer and Huxley with such a force of logic that it captured almost the whole thinking world. "I marvel," said Lord Kelvin, "at

the undue haste with which teachers in our universities and preachers in our pulpits are restating truth in the terms of Evolution, while Evolution itself remains an unknown hypothesis in the laboratories of science."

But to-day Darwinism is a dying creed, held by only a few conservative scientists, and most scientists recognise that it is moribund.

"The conception of evolution," said Bateson, "as proceeding through the gradual transformation of masses of individuals by the accumulation of impalpable changes is one that the study of genetics shows immediately to be false. Once for all the burden so gratuitously undertaken in ignorance of genetic physiology by the evolutionists of the last century must be cast into oblivion." Again: "The fair truth is that Darwinian Selection theories, considered with regard to their claimed capacity to be an independently sufficient mechanical explanation of descent, stands to-day seriously discredited in the biological world." Again: "It is impossible for scientists longer to agree with Darwin's theory of the origin of species."

A belief in continuous genetic evolution of some kind, however, still prevails, but there is a growing recognition that *if* all the multicellular organisms were genetically evolved from unicellular organisns there must have been an inner prescient drive of some kind in various definite purposive directions. It is also generally believed to-day that evolution proceeded by successful leaps—by happy co-ordinated mutations, rather than by small hit-or-miss variations, and many men of science

are now making desperate efforts to explain these successful, fortunate, happy mutations without postulating the intervention of mind. But some big men of science are already surrendering belief in anoetic evolution. The theory of "emergent evolution," for instance, assumes that causality has not been continuous, but that at various points in the evolution of life quite new causal machinery, competent to produce quite new effects, under quite new laws, has been introduced—that life accordingly is *more* than inevitable result of the causal machinery at work in dead matter, that mind is more than the inevitable result of the chemical processes which occur in the chemical compound called protoplasm, that teleology plays a part as well as *vis a tergo*.

Lloyd Morgan, who introduced or at least elaborated the idea of emergent evolution, says—as I said twenty years ago—"The activity we feel when through exercise of the will we are ourselves causes, best illustrates what is meant by causal activity. Carry this a step further, lifting it to a higher plane of thought, and we have the widely accepted belief that ultimately all observable change is due to spiritual activity."

And Professor Sir J. Arthur Thomson, the most cultured, learned, and charming of all modern evolutionists, declares: "It looks as if Nature were Nature for a purpose, and as we cannot predicate purpose in a vast system we must reverently ascribe it to a Creator. We plead that the evolutionist picture is in harmony with the Vision of God."

It seems to me personally that we must postulate purpose in Nature, that there is no reason to believe in continuous genetic evolution, and anoetic genetic evolution as generally conceived is a futile effort to escape from the idea of a Creator.

One of the most amazing consequences of the theory of continuous genetic evolution from amœba to man—however the genetic evolution may be explained—is the almost incredible continuity of the germplasm in space and time. The idea even that every living man to-day is linked by a chain of millions and millions of germplasm buds—fertilised ova—to man who lived perhaps three million years ago is in itself amazing. Genetic evolution, of course, to that extent I believe. It amazes me to think that the little particle of protoplasm that grew into me was millions of years old and linked to the first man who ever lived. It amazes me to think that a chain of minute eggs each the size of a full stop bind me in a network with every man and woman who is alive, and has ever lived. A line a few yards long of almost invisible cells that so far as length and size go might be put in my waistcoat pocket binds me to Adam, and contained in itself the potential bodies of thousands of my ancestors. Like a fire tended by vestal virgins the fire of life has never gone out during all these æons. Like a torch handed on from runner to runner the flame of life has never been passed off from bud to bud. All down the æons the bodies that transmitted the germplasm had to fight to live, and every man alive to-day is, as living protoplasm, millions

of years old, bound to the first man by a necklace a few yards long. And each tiny bead in the necklace gave birth in the body of each man to millions of body cells—in every man's brain alone there are 50,000,000 brain cells, and the red blood cells he forms in a lifetime would reach several times to the sun. If all the germ-cell chains that have genetically united all men ever born to their first forefathers were put in a line, the line would reach perhaps a few yards, while if all the red cells made by these germ-cells in the course of the lifetime of men were put in a line they would reach millions of millions of miles. Such vital energy is there in living matter in its reactions to its environment, such an anti-climax of immensities is a baby in one sense, such a consummation of eternities is he in another!

Such a realisation of the genetic relationship of man even as a separate species almost overwhelms the imagination, but if we accept, as most men of science accept, a theory of continuous genetic evolution and consider the germplasm of a man and of all animals as continuous in space and time, we have to try to picture a still more amazing prodigy. In that case the germplasm of modern man is in budded continuity with all the living species from which Man traces descent. We must picture a budding process that has gone on for perhaps four thousand million years. We must picture a network of linked buds big enough to snare and mesh the whole world of life; and we must believe that as the germplasm budded, bud after bud,

along these prodigious chains, it altered in its characters at intervals, so that a bud which began by producing amœbæ or foraminiferæ began at a later stage to produce worms, and thereafter to produce oysters, and thereafter fish, and thereafter amphibians, and thereafter reptiles, and thereafter birds, and thereafter mammals, and Newtons, and Shakespeares. If our imagination is strong enough we can picture dangling in consecutive serial place from buds in the net of life all living creatures, crabs, humming-birds, iguanodons, whales, mammoths, lice, babies—a yard or two of amœbæ, and then a few thousand miles of foraminiferæ, and then a few thousand miles of fish eggs, and a few thousand miles of reptilian and avian eggs—each chain at a certain point changing gradually, or suddenly, in part, or whole into something new, and strange, and ingeniously perfect. And think in such a case what an inexplicable momentous thing death is. For thousands of million years, according to theory, an amœba egg has been transforming itself into a human ovum—what æons have gone to the transformation, what millions of deaths, what millions of hairbreadth escapes from death, what ingenious changes of gills into lungs and shoulder-girdles, of fins into feet, and so on! and at last there is a man, a great thinker or a great artist—the consummation of all these æons of miraculous evolution. But death comes and slays him before he has bred, and the marvellous transmuted and transmuting germplasm three hundred million years old, kneaded and wrought for three hundred million years,

is ended for ever. In the dead body of the man is coffined the apparently potentially immortal stuff that came down mutating and evolving for hundreds of million years, and might have gone on mutating and evolving hundreds of million years more. In every dead animal that has not bred die worlds of the past and the future—a world of ancient creatures, and a world of creatures that might have been. So big, so little, so mysterious is life.

On the theory of continuous genetic evolution, man is thousands of millions of years old, and with every man who dies without a child perishes æons of marvellous evolutionary effort. For myself I cannot destroy a midge without thinking of the marvellous delicate mechanism I destroy, and when I conceive of it as the work of millions of years I am more inclined to worship than destroy.

Another very amazing thought inherent in the continuous genetic theory of evolution is the thought that while some amœbæ have grown into men, some have not only remained amœbæ, but have become deadly foes of man. We find alongside all the various creatures, that are supposed by evolutionists to have been the fruit of germinal variations, ancestral creatures either in direct or collateral lines quite unchanged for millions of years—such creatures as bacteria, and sharks, and crabs, and lancelets, and worms.

Nor, if we accept continuous genetic evolution, can we escape from a great speculation. If all the creatures alive to-day have arrived and progressed and crossed

from one family to another through germinal variations—if amœbæ have grown into butterflies and larks—if tree-shrews and monkeys have grown into men, is it not possible that men may progress still further till he is as much above man as man is above a marmoset—is it not possible that amœbæ, and fishes, and monkeys, and all the lower orders have still unrealised potentialities, and that some descendant of a bird, or lizard, or fish, or gorilla may one day quite outstrip man? It is a big speculation which I have treated too briefly and inadequately in my brochure *The Body of To-morrow*, and that here I can merely mention.

I myself do not believe in the theory of continuous evolution, except as a possible, unproven hypothesis, but it is held in some form or other by most scientific men of to-day, and in our survey of man from various sides, this side must not be neglected and must be given due weight.

CHAPTER XI

HEALTH, OLD AGE, DISEASE, DEATH

" Verily thou art a God that hides Thyself."—ISAIAH.

" But though the Lord conceal Himself from the eyes of the sensual and lazy, who will not be at the least expense of thought, yet to an unbiassed and attentive mind nothing can be more plainly legible than the intimate presence of an All-Wise Spirit who fashions, regulates, and sustains the whole system of being."—BISHOP BERKELEY.

" He is not far from every one of us."

THE birth of a man, as we have seen, is more than a mundane, it is a cosmic episode. Though man begin as a dot—apparently chosen and fertilised more or less by chance—it is yet a dot that, according to evolutionists, can trace living ancestors so numerous that their tiny ova placed in a row would reach thousands of miles back into space, and millions of years back into time, to beginnings in the fiery molecules of a star. Through what perils, and tribulations, and transformations the tiny dot must have passed, our recent survey has shown us.

Having arrived after such a long and adventurous and hazardous journey through time and space from a star to a womb, the little fertilised ovum buds and multiplies into a thousand million cells and becomes the wonderful thing called a man. And when we consider the marvel of a man's body and the myriad-

ness of his mind, the eternities of moil and toil seem almost worth while. A man like a Newton, or a Tennyson, or a Jeans, or a Sir Walter Scott, or a Captain Scott, or a Clerk Maxwell, or a Savonarola, or a Bishop Berkeley, might seem an explanation, and justification, and interpretation, and consummation of the whole cosmos.

But even after Man is born, and stands on his planet spinning through space, he is pursued by multitudinous perils ; in him the work of æons may abort, the whole amazing line of inheritance come suddenly to an end for ever. He has to fight the inorganic universe that bore him : he has to grapple with evil stars, and cataracts, and tornadoes, and fires. According to evolution, as amœba, and fish, and lemur, and ape, he has run the gauntlet of millions of greedy deaths. And to-day the same volcanoes that made breath for him may choke him and bury him, the same sea waters that run in his veins may overwhelm and drown him, the same sun that worked in the green leaf for him to give him energy, may smite him dead. Or some of his animal kin—a tiger or a lion—may destroy him, or even some bomb thrown at him in the name of God by a military and patriotic brother. And with him—if he have no offspring—will perish millions of years of life behind, and millions of years of life before—perhaps—as in the case of Moseley, slain at Gallipoli—will perish splendid transmissible faculties of a great brain that Nature took millions of years to perfect and may never achieve again. What are we to make of a Maker who

toils for millions of years to make a marvellous thing and then allows His own wonderful work to be so wantonly wasted? Even if a man escape for threescore, fourscore, fivescore years, old age in the end will cripple him, and death in the end will slay him, and decay will turn his marvellous body into ammonia, and water, and gas. No courage, no wisdom, no strength, will save him. Was so perishable a thing worth all these æons of toil and tribulation?

We have pointed out the great past of the body, the infinite patience and skill which made it, the infinite fiery hands that moulded it, the infinite wisdom that co-ordinated its cells and made it an obedient versatile servant of our will, and a minister of joy. But what are we to make of Disease, and Old Age, and Death, which undo everything and sooner or later destroy the body?

Personally I do not know—I can only say that though He slay me, I who have seen the greatness and glory and wisdom of His Works must trust Him, and that I will fall without fear and shuddering on the heart of Him that made the rose. How can I presume to doubt the love and wisdom of the Power who wove one thousand million cells in my brain, making me able to see universes countless million miles away, to watch the electrons waltzing and leaping in the atoms of a star, to measure the waves of the cosmic rays flowing from the Milky Way?

> "The mystery of life and death
> I neither fear nor understand.
> Why fear the Power that gives me breath
> And comes with roses in His Hand,

> Who binds the stars like silver braid
> Upon His brow and on His breast,
> Why should my spirit be afraid?
> His love is wise and knoweth best."

In such a spirit, then, let us look at man as a mortal organism liable to disease, old age, and death. Let us face the facts and refuse to gloze them even when they seem painful, yet let us face them in the faith that the Maker is wise, and that all things work for good.

Let us consider first in a general way the question of health. How are we to define health—this something that so many people vaguely crave for?

To some people who suffer from pain, health means little more than freedom from pain and discomfort. To other people whose vitality is not equal to their bodily activities it means more muscular energy. To those with actual disease or wounds it means recovery in these respects. In such senses as these all people crave for health. By almost all, the term "health" is restricted to the physical side of a man's experience.

But the word "health" in its etymological meaning connotes wholeness, and I think that it should be used with reference both to mind and body, and that it should be used to denote that condition of mind and body which permits of the most happy, harmonious, and useful activities both mental and physical. A man may have a mind capable of coping with the integral calculus, but if in the Brownian sense "calculus racks him" he is hardly *integer vitæ* however integral the calculi may be. Nor is a man a healthy man in the sense of wholeness of life, though he hold the record for the quarter-

mile and hurdles, if he cannot run with joy across the *pons asinorum*, and if he find no pleasure in intellectual athleticism. No man is a healthy man, however strong his muscles, if he have a weak mind, nor can a man be a healthy man, however strong his mind, if his body be feeble. I hold that the healthiest man is the man who is able effectively and happily to use all his faculties, mental and physical, in proportion to their several importance in his personality and environment. Harmony and wholeness more than mere vigour are what men should crave for under the term "health." At least, a comprehensive and harmonious and proportionate exercise of all a man's faculties mental and physical will certainly bring a deeper and more abiding sense of health to the man and to his fellow-men, than any one-sided development.

A man's body is a beautifully co-ordinated complex where every cell is bound to every other cell and where one cell cannot be starved without the whole community suffering, and a man's personality is equally a co-ordinated complex, and must be developed as a whole and act as a whole. Though, of course, just as there are many kinds of bodies and minds so there are various degrees and possibilities of health in the sense in which I now use the word.

To-day physical energy has been given, I think, an undue place in health-culture, for over-development and over-use of muscles produce a disharmony in personality which is incompatible with the highest health and happiness.

Nevertheless, for all activities both mental and muscular, physical energy is required, and so physical energy must be in some degree the basis of health, and to some extent its criterion.

Now where does physical energy come from, and why should it vary in amount? Why should one man be in energy a millionaire and another a pauper, even though both have equally good food? Every man is made of the same chemical matter protoplasm, and all protoplasm is energised by the sun. Why is there not equality in amount of energy, even if there be difference in the ways in which it is expended?

That is a difficult question; but probably even as germplasm has varied to produce tall men and short men, black men and white men, so also it has varied and varies to produce buds with more or less capacity for building into themselves and in exploding the energy-producing molecules of food substances—in other words, cells seem to be produced with innate greater or less digestive, assimilative, and explosive faculty. The energy is in the food right enough, but a cell may be "slow in the uptak" or slow in the *upbrak*.

Even when the germplasm has originally good assimilative capacity, lack of energy may result from the fact that the mother's blood has not supplied the cells of the embryo with sufficient food to build up their living substance to dynamic perfection. Or it may result from the fact that after birth the baby has been given cows' instead of mother's milk, and so has built up protoplasm with less energy content. A badly fed

or an ill mother and a badly fed baby leads to a lack of energy in a man even of good stock.

Again, there would seem to be some stocks of germplasm in which the higher nerve cells are capable of particularly vigorous assimilation, and other stocks in which the higher assimilative power is possessed by lower nerve centres. But food, and assimilative capacity, and innate constitution, are not the sole determinants of energy.

To make out of the food the vital explosive on which energy depends there must also be a good supply of oxygen, and if this supply is deficient in the first weeks, months, and years of life, all the tissues will be built up, so to speak, at lower levels of pressure, and will probably be more or less deficient in energy all through life. A baby or a child deprived of exercise in the fresh air can hardly develop into a vigorous adult even if it come of vigorous germplasm.

Lack of food and oxygen in later life may also cause lack of energy, even in adults of good stock who have had healthy babyhoods and childhoods, but in such cases physique is usually better, the lack is better tolerated, and the debility can be usually easily cured by good food and fresh air.

Given the energy, there is next the question of its distribution. Luckily, a great part of the distribution is not in our hands—most of the energy is automatically allotted to the organs that have most to do with providing it, the digestive organs, the heart, the respiratory organs, the reproductive organs, and the brain. The

brain, even of those who have least belief in brains, is particularly well supplied with energy, and so such brain-health as the energy is capable of providing is assured. Still, a certain considerable amount of energy is at the disposal of our volition, and we can obtain more by robbing to some extent the vital organs of the energy that should be theirs, and it is here, and in the application of the energy at the disposal of our volition, that health in the highest sense of harmony and health usually suffers. Either too much energy is devoted to mental work and often to one kind of mental work, or too much is devoted to physical work and often to one kind of physical work, and the result is unhappiness, disharmony, and unhealthiness of personality. This unharmonious distribution is often compelled by economic pressure, and it is one of the saddest things in civilisation that its demands for physical and mechanical energy should often be at the expense of mind and soul, and that the higher faculties are so often sacrificed in order to make a livelihood. A man who sits cross-legged most of his life and pushes a needle through cloth is only the ninth part of a man, and has only the ninth part of health. A man unable to marry lacks his better half, and is more than half an invalid. A man who spends all his life breaking stones can never get the blood of real health out of them. It is a disgrace to civilisation that any man should be denied the opportunity of using the best faculties of his heart, and mind, and body, and that he should be compelled to be a mere cog in a machine—he, son of the Sun, "heir of all the

ages." There have been few more fatal steps in the march of humanity than the steps that have led millions of English men and women to be entombed in the "verdumpftes Mauer-Loch" of factories.

It is a cruel and bloody chapter in the history of humanity—a chapter, I hope, almost finished. Indeed, the very machines to which, as to the body of a dead man, man's living bodies have been bound may be in the end Man's great emancipators.

But it is not economic pressure but ignorance of the laws of health and happiness that is the most common cause of paretic, unhealthy, lop-sided lives. Men and women have not learnt the happiness and the healthiness of many-sided activities, and especially of the mental happiness and the healthiness to be found in intellectual, and spiritual, and æsthetic applications of the energy lent them by the sun. We have beautifully co-ordinated motor centres in our cerebrum, we have five hundred marvellously made muscles, and we need only touch a button with our will to set the whole thing in motion—a motion that is part of the whole vital revelation of man to himself. Let us then dance, and climb hills, and run, and walk, and swim, and breathe deep, and enjoy our food, and get firm muscles and steady hearts. But let us remember, too, this very suggestive and illuminating fact that only a few of the one thousand million cells in the brain seem meant for muscular activities, and that most of them seem meant to produce in us through the senses, thoughts, and feelings—such thoughts and feelings as will give us an

intellectual and emotional vision of the largeness of life and of God in us and in all things, including, of course, the physical pleasures of life. Health, in any consistent sense of the idea, must mean not only the efficient functioning of heart and liver or muscles with the sense of happiness, and *être*, and *bien être*, that such functioning of the faculties of the mind which have made us more than apes—functioning that gives us an even greater sense of happiness, and *être*, and *bien être*, than we can ever obtain from energy directed solely into physical channels. It seems to me that to-day this law of health is ignored and forgotten. People use their brains under protest just to get on—to make money and buy motor-cars; and love of knowledge, and beauty, and wisdom, and goodness for their own sake is being lost. Hence spiritually and intellectually the world to-day is much less happy and healthy and much more restless and feverish than it was some decades ago.

Health is wholeness resulting from energy rightly directed, and in wholeness is happiness, and holiness.

But our bodies and minds have to face the fact of disease, not only such disease as is preventible by wise living—by exercise, food, and fresh air, body and mind —but disease from which no wisdom to-day can always save us; sometimes inherited disease, sometimes disease that in the course of life we have knowingly to face, sometimes infectious disease that we are unable always to avoid; and these diseases, even if they do not kill us, may diminish our store of energy, or cripple our

mental or physical faculties, and rob us of all *bien être*.

Every organ, every tissue in the body is liable to disease. The heart, through no fault of its owner, may become leaky, and the body-cells, deprived of oxygen and food, may suffer from famine and degenerate. The arteries may lose their elasticity, and a little artery in the brain may burst and all the wonderful mechanism of speech and locomotion be destroyed in a single moment. The pancreas may secrete insufficient insulin, and so the cells of the body may be unable to use the sugar in the blood. The white cells of the blood may multiply too fast and produce the fatal disease leucocythæmia. The thyroid may secrete too much of its "hormone" and produce the condition known as "exophthalmic goitre," or it may secrete too little and cause "cretinism." The little pituitary gland may become too active and produce "giantism"—deformities of the bones, of the face, and hands, and feet. Various cells may multiply too rapidly and produce terrible tumours. Even the sun may turn against us and drive a sword into the delicate tissues of the brain. But why proceed? There are huge tomes filled with accounts of diseases to which man is heir, and when we read them we wonder that there are any healthy men at all in the world.

Most common of all the diseases are the diseases caused by the tiny cohorts of death known as microbes —some are of vegetable, some of animal nature, some have been seen and identified, some are still to find and identify. Man is now master of the big beasts of

prey: the mammoth and sabre-toothed tiger are no more; the complexes of the human brain have devised cunning ways of slaying all the dangerous predaceous animals still a danger. But the ancient, microscopic, unicellular creatures that were born millions of years before man appeared on the scene, still menace him, and still wage relentless warfare against him, and even if they do not slay him they at least succeed in reducing his health. They maim and murder almost quite indiscriminately—young and old, weak and strong, dark and fair, male and female; and their methods of warfare are subtle and various. They enter man's tissues with his food, with his breath: they creep in at cuts and pores: they make aeroplanes of the dust and war-chariots of the insects. Most of them are smaller even than the blood-corpuscles, but they kill and maim by poisons, and by poison-gases.

How many millions were slain by plague in the Middle Ages we do not know; but the influenza epidemic of 1918 slew more men than were slain during the whole Great War, and every year in India alone a million people were massacred by malaria germs inoculated by mosquitoes, while it is believed that it was malaria that brought about the decline and fall of Ancient Greece. Think of the ravages of small-pox! In the West Indies, in 1507, whole tribes were exterminated. In 1590 all the Indians of the cities of Potosi and De la Paz were swept away. In Mexico, 3,500,000 were suddenly slain and none left to bury them. Consumption, the white plague, has been almost equally

lethal: it slays yearly 100,000 Anglo-Saxons, and it has desolated whole islands in Polynesia.

How are men to maintain a high level of health when there are millions of microbes assaulting, and besieging, and wounding, and disabling, and killing them? What advantages it to have marvellous bodies if they are to be thus treacherously assailed and destroyed? Do not such massacres of men by microbes not render it impossible to believe in a Providence?

These are difficult questions to answer. Certainly in thousands of cases men are deprived of health through no fault of their own, and have to live mean and miserable lives that seem hardly worth living, and it is difficult to find any good in such evil. Still we know that disease and death have done a good deal to make the world of life as it is to-day, and that *perhaps* without their selective sieving man would not be in the proud position he is to-day. No doubt it was disease that killed out the great reptiles, and many of the predaceous animals of the prehistoric world, and no doubt to-day, though we may not be able to see it, disease is still selecting and making for progress. And if one points out that the tubercle bacillus killed such distinguished men and women as Spinoza, Schiller, Laurence Sterne, Henry Kirk White, John Keats, Chopin, Robert Louis Stevenson, Marie Bashkirtseff, Thoreau, George Gissing, yet one must notice also the fact that consumption is particularly common in stock subject to mental disease, and that a big scythe must sometimes reap flowers as well as weeds.

That is not a sufficient explanation, I know; it only half explains *slaying* by microbes; it does not explain at all *maiming* by microbes. Still it at least suggests that death and disease may not be quite so blind and indiscriminate as they appear. Again, though health of mind and body may be the ideal that seems to us one of the highest ideals we can aim at, and though nature through selection by disease, and man himself by medical progress, is making that ideal ever more possible for most of us, yet it is certain that death does not end life and that deprivations in life—deprivations of health and happiness—deprivations of full mental and physical power—may be preparations for something better than health and happiness beyond life. I do not know, but when I see the perfection with which—judged by human standards—living organisms are made and out of what amazing darkness they came—when I consider the intricacy and precision with which parts are fitted to parts, and combinations of parts are built up into greater wholes—I am constrained to believe that in a wider synthesis than we can yet comprehend, even diseases and deprivations may become splendid aggrandisements. In a few chosen cases we see it: we see men and women just through their burdens becoming wise, and through their fetters becoming free.

Such considerations as these last can, of course, apply only to a few cases; they offer no explanation and no consolation in cases where there is complete disablement of mind and body, but for these, as I have said, we may find an explanation far away. The mills

of God grind slowly, and the rock crushed beneath the heavy heel of a glacier may feed roses still unborn, and "the briny tears that mortals weep may water lilies on a star."

Meantime, science has been fighting disease—the brain-cells of man have found ways of treating the ailments and disorders of some of the other cells of the body, and have particularly pitted themselves against their murderous little ancestors, the microbes. In both departments great victories have been won. Let us mention a few of them.

We have spoken of the disease due to insufficient activity of the little gland in the neck called the thyroid, and for these a successful method of treatment was discovered some years ago. It was discovered in 1891 by Dr. Murray of Newcastle, that the conditions known as myxœdema, and goitre, and cretinism could be cured, or at least alleviated, by injecting a little thyroid extract under the skin. The cure of myxœdema affected by thyroid extract is most sensational. In that ugly disease all the features—cheeks, nose, lips, and chin—become coarsened, swollen, and enlarged: the lower eyelids become baggy, the upper eyelids hang down over the eyeballs, and the expression of the face becomes heavy and stupid. The neck, abdomen, hands, and feet also swell, the muscular and nervous system are both enfeebled, the hair, nails, and teeth all suffer from malnutrition. Memory is impaired and all the mental processes are defective and slow. But as soon as the extract is injected the condition improves, and in a few

weeks all the symptoms disappear and the patient is full of energy and bright of countenance. This led to other treatments on the same principle, and a few years ago, Dr. Banting of Toronto and Professor Macleod discovered that the symptoms of the terrible disease diabetes can be removed by administration of an extract from the pancreas called "insulin." In the treatment of cancer, too, successes have been won, for treatment by radium and X-rays have effected quite a number of cures, and Finsen's treatment of lupus by ultra-violet light was a brilliant victory over disease.

These were certainly great victories, but over the microbes equally great victories have been won. In 1796, long before microbes had been caught *in flagrante delicto*, Dr. Jenner made the great discovery that by inoculation of cow-pox, human beings could be rendered immune to small-pox, and the discovery robbed that ugly disease of half its terror. In 1863, Davaine and Rayer discovered the first microbe of disease—the anthrax bacillus; and, in 1881, Pasteur discovered a protective vaccine against it. In 1864, Semmelweiss instituted empirical antiseptic measures against puerperal fever; and in 1865 Lister commenced to put antisepsis and asepsis on a scientific basis, and finally established the antiseptic treatment that has saved millions of lives. In 1882, by means of dyes, Koch found the *Bacillus tuberculosis*, and though no vaccine or serum has been discovered to combat it, yet cleanliness, sanitation, and open-air treatment, and precautions against infection, are gradually exterminating

it. In 1890, Kitasato and Von Behring made the great discovery of an anti-diphtheritic serum. In 1880, Laveran identified and convicted the germ of malaria; and a few years later Sir Ronald Ross found out that the anopheles mosquito inoculated the germ by its bite and thus suggested preventive measures which have exterminated the disease in many districts, and rendered habitable vast areas of rich land hitherto too malarious to be habitable. Finally, a few years ago, Dr. Jauregg von Wagner of Vienna found out that the malaria germ can be used to fight General Paralysis of the Insane, perhaps the most terrible and incurable of all diseases.

These are only a few of the victories of science over disease, but they are sufficient to show that probably in time all diseases will be curable, even if not eradicable, and that in respect of disease man will have unimpaired health, and unimpaired mental and physical energy. Science is conquering disease, even though she cannot quite see why such conquest should be necessary in a world so full of good and friendly things.

I should much like to discuss the question of eugenics here, and also the question whether the saving of weakly lives is not causing racial degeneration; but the subject is too big, and I must pass on to another smaller controversial matter—the matter of the meaning of pain.

What is the meaning of pain? Why should birth mean pain, and death mean pain?

The question has been discussed for centuries, and I do not know that science can shed much light on it. But a few striking facts may be noticed. Firstly, man's

capacity for pain is limited. Secondly, "Nature's stamp of merit is capacity for pain." Thirdly, pain is conservative and preserves the tissues. With regard to the first point, one knows that men have had legs blown off, and have felt it only as if it were a heavy blow with a stick, and ghastly injuries often pain less than a cut finger. Fourthly, pain acute beyond a certain point is followed by insensibility. With regard to the second point, it would seem that pain is the price paid for a highly developed nervous system, capable of vibrating to pleasurable sensations, and that usually pain in a wound is a healthy sign and encourages a favourable prognosis. With regard to the third point, there can be little doubt that if injury did not cause pain we would often lose parts of the body, and where any form of paralysis deprives a part of sense of pain, it is very difficult to preserve it from injury. Further, it may be remarked that pain is not numerically cumulative. If fifty men have toothache there is not pain fifty times as severe. And lastly, it may be stated that death itself is rarely painful, and that the carbon dioxide which accumulates in the blood of the dying acts as an anæsthetic.

But, alas, that is all one can say; and one has to face the great fact that many people have to endure again and again acute and almost intolerable mental and physical pain, and that many have to face chronic pain if not so agonising yet equally or more intolerable. Why that should be we do not know; and though we can rejoice that science has found ways of relieving or

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anæsthetising most of the physical pains to which man is liable, we cannot explain why such pain should be, and why for thousands of years before anæsthetics were discovered men had to suffer such martyrdom.

In some ways more terrible than bad health and disease and pain is old age. It is terrible because it is inevitable and irremediable. A man may fight bravely against ill-health, disease, and pain, and sometimes win the battle, and even if he lose he has usually still some reserve of energy. But old age slowly and steadily drain a man of energy, and with energy of courage, and hope, and force. No longer can the old man hope ahead, the future holds no redemption, only a lingering death. The firm muscles waste, the features sag, the eyes grow dim, the limbs grow feeble, the heart grows weary, and the brain works slowly. The graveyards fill with old friends, the old familiar faces are no more. There can be few things more tragic than to see a strong beautiful mind, a strong beautiful body, slowly decay. There can be nothing more tragic than for an old man with his life work unfulfilled, with none of his own blood to follow him, feeling his last strength of mind and body gradually ebb away. Browning may cry, "Grow old along with me, the best is yet to be"; Shakespeare may talk of "hale and kindly old age"; Longfellow may talk of "old age as lovely as a Lapland night"; and Henley of "late lars ksinging"—but there is a point when the best turns the worst, and when hale and kindly old age stands chill and tottery, when the grasshopper becomes a burden, and the stars corpse-candles of dead hopes.

What has science to say about old age? Can it cure it? Can it show it in any divine light in the workhouse, in the infirmary, in the bath-chair?

> "It is a strange and dreadful thing to die—
> More cruel are the pangs of growing old,
> With sacrifice of doves, with song and sigh.
> O Death, we ring thy moonlit altar cold!
> But we protest with agony and rage,
> Hateful the gross indignity of age,
> With all the banners of our beauty set
> To break with trumpets o'er the twilit Mark,
> Affront and storm the bastions of the Dark
> In one great gust of music and regret—
> Ere the gold crown-imperial ravished be
> And from the breast the scent of roses fade—
> So might this fair adventure end—woe's me!
> Conclusion unafraid,
> Mournful, yet sweet and strange!
> But to eat ashes ere we fall to dust,
> By dull degrees of deflagrating change,
> By slow deflowering of dim disgust
> Put on Mortality!" R. A. Taylor.

Science has not yet cured old age, and science never can cure it till she has found the secret of immortality. But science, in making better health possible, has at least postponed the disabilities of old age. To-day we find men vigorous enough in soul and body till well on in the eighties, and that is something.

Claims have been made out that by grafting glands or by administering gland extracts men can be rejuvenated, but the claims made by the rejuvenators—by Voronoff and Steinach and others—will not bear critical examination. No one gland, and no gland extract will ever rejuvenate a man, for all the cells and all the glands act and interact on each other, and a chain is no stronger

than its weakest link. We can prolong youth only by prolonging the healthy interaction of all the cells and *all* the functions so far as their actions and functions are in our control, and we can prolong them mainly by measures that improve the general health, by the right amounts of the right sorts of food, by the right amounts of the right sorts of rest and exercise, by intellectual interests, by good cheer, by happiness.

It may even be maintained that the mind never really ages, though its active energy may be eventually hampered by decay of the body. Dr. Rudolf Otto, holding that belief, writes in his *Naturalism and Religion*: "Naturalism is also only apparently right in asserting that the mind ages with the body. . . . The arguments put forward by naturalism, the blunting of the senses, the failing of memory, are well known, but here again there are luminous facts on the other side which are much less true. It is no wonder that a mind ages if it has never taken life seriously, never consolidated itself to individual and definite being through education and self-culture, and through a deepening of morality, and has gained for itself no control of lasting worth. How could it do otherwise than become poor, dull, and lifeless, as the excitability of its organs diminishes, and its susceptibility to external impressions disappears? But did Goethe become old? Did not Schleiermacher, frail and ailing as he was by nature, prove the truth of what he wrote in his youth, that there is no aging of the mind."

The whole problem in its highest aspects is a question

of will and faith. If I know mind and the nature of mind, and believe in it, I believe with Schleiermacher in "eternal youth."

Were we a single cell or made of one simple tissue, we might prolong life in a sense indefinitely. Life at its lowest or simplest is simply a matter of a soup-basin and a wash-basin, and an individual cell of the body put into a drop of fresh serum and washed free of waste products, and supplied with fresh food and warmth, will go on multiplying apparently for ever. Cells detached from the embryo of a fowl have multiplied for more than fourteen years—about three times as long as a fowl lives; and if some one were to take a few cells of Ramsay Macdonald to-day, and put them in a culture fluid, and were to appoint some vestal virgins to look after them, a bit of Ramsay Macdonald put on exhibition might draw a crowd in 2030.

Cells, however, that live and multiply this way lose their special structure. We sell bodily immortality at the price of multiplicity and specialisation, and the price is worth paying. We cannot both be mortals and immortals, but the immortal reproductive life of a single cell at least suggests that life and youth and vigour might be at least prolonged even in complex multicellular individuals by suitable food, and by keeping the tissues free from waste products that poison them, and it is not unlikely that when doctors have succeeded in banishing disease from the world and have solved a few dietetic problems—it is not unlikely, it is even probable, that we may all live to be centenarians.

Still, in time, old age and death must come, for it seems certain that just as there is a limit to growth in the multicellular body, so there is a limit to life. I believe that something *not material* assembles and arranges the cells of the multicellular body, forming a co-operative colony, and afterwards partially directs them, but that even as the assemblage and arrangement cease, at a certain point, to produce further growth, so by their intrinsic constitution, by their own inherent evolution, the assemblage and arrangement arrive at a stage of disharmony and dissolution. The mind body that, working in the germplasm, made the body, made it in such a way that at a certain point—a point only partially dependent on controllable environmental conditions—it will go to pieces.

The same prescient mento-volition—the tremendous and mysterious power that made the protoplasm, that made the cells divide and cohere and arrange themselves in a co-operative colony, also, and at the same time, pre-arranged in the constitution of the multicellular organisms an eventual date of dissolution, and it is just as impossible for us to make life go on for ever as to make day go on for ever. As in the rotation of the Earth night follows day, so in the processes of the body death follows life. Even if we could make life we could not annul death ; and life seems to have been made by a thinking and omniscient Being with infinite wisdom and energy such as we can never possess—everything science knows about life proves that, and it is time, I think, that science frankly said so.

I am not a fundamentalist. I do not believe in the verbal inspiration of the Scriptures, but poetry sometimes comes nearer to truth than science, and I hold that the old Hebrew prophet's conception of breath from the nostrils of God represents, as well as it can be represented by a finite intelligence, the fact that life was and is a special creation by a Conscious Will.

Disease will come, or has come to most of us ; to all of us old age and death *must* come, but disease to some extent can be fought and to some extent retarded, and old age and death to a great extent fearlessly, even hopefully, faced. If we make the best of our mind and body, even disease and old age will leave to most of us almost until the end enough health to make life still worth living, and death will seem as full of promise as birth. I believe that the mind that, under guidance of a great Mind, uses body and brain, will come forth victorious in the end. I believe this because I see in the body and in the development of the body not chemical reactions giving rise through the body to a mind, but rather a mind within an omnipotent omniscient Mind *using* the marvellous body ; and even after the body's decay, feeling and proving its own independent greatness.

A mind able to move and use a body so superlatively marvellous—a mind that holds in itself the sky, the sea, and the universe—a mind that seems to be in touch with its Maker, need not fear the ills that mortal flesh is heir to, for surely it has in itself tokens and intimations of immortality.

CHAPTER XII

GOD AND MAN

"The old saying *Crede ut intelligas* may be annexed by philosophy." —L. STEPHEN.

"I believe that no rational man doubts the existence of intelligence in the universe, even as no physicist denies the existence of magnetism. This being the case, I do not understand why men do not make use of intelligence to explain facts which certainly can be best explained through the activity of intelligence."—PROFESSOR KRÖNIG.

IN our previous chapters we have regarded Man through the eyes of many sciences. We have seen him as an animal among animals dangling from a chain of germplasm along with amœba and atlantosauri, and sharks and shrews and monkeys. We have seen him as a wonderful weft of microscopic cells. We have seen him as a marvellous structure of co-ordinated organs. We have seen his life beginning in a lightning cloud, or in a muddy volcanic puddle. We have seen his abode as a shred of a nebula. We have found in all his energies the energy of the sun and have studied some of the myriad intricate environmental and intracorporeal correspondences essential for his being. We have marvelled at the wisdom of his body. Finally, we have analysed his substance and the substance of all things into protons and flying electrons, and have found that to physics man in ultimate analysis is nothing but

a saltspoonful of these invisible electric particles. We have found infinitudes in his infinitesmals, and infinitesmals in his infinitudes—"boundless inward in the atom, boundless outward in the whole."

All these points of view may be considered true and illuminating points of view, and yet it is not easy to integrate them. Each point of view seems rather to give us an independent conception of man. How can we integrate such physico-chemical processes as karyokinesis with the conception of man as ether thinly pervaded by flying electrons? How can we reconcile the view of man as red blood, and white bone, and blue eyes, with the view of him as a Milky Way of electric constellations? What light does it throw on the man who laces his boots and buttons his collar when we trace him back to an amœba, or to a speck of protoplasm in his mother's womb?

Do these views of science in any deep way explain man or make life more worth living? Do they not rather make man and life still more inexplicable? The origin of life, the building of the body in the womb, the evolution of animals, the nature of voluntary action, the relationship between matter as now understood, and mind, remain, as before, great mysteries. Man is not greater in stature when we compare him with a nebula, nor does he become more rational when we regard him as flying electric charges. And even if we do not accept the Darwinian doctrine of his origin by chance selection of chance variation, science is often compelled to see something very like chance at work. One sperm and

germ-cell out of thousands grew into a Shakespeare, the others perished. Was it a rational principle that guided this selection? The wind blows a few germs into a baby's milk, and the baby dies. Is there chance or wisdom in that breath of Death?

"Surely it is a whirl of Chance
This ever-changing atom-dance
Of dust and wind,
Of brain and mind,
Of variant and circumstance;
And if a Spirit be behind
He must be deaf: he must be blind.

In mist of fire the world began,
But was there prescience in its plan
Was it decreed
That one small seed
Should grow into a living man,
And one for æons only breed
A trilobite, a worm, a weed?

Was it decreed? A micron swerve
In some swift atom's orbit-curve
Had changed its goal
In sense or soul,
In blood or blossom, node or nerve;
And how could prescient Will control
The intricate rhythms of the whole?

A million deaths as worm or ape
We had to combat or escape—
Talon, and claw,
And tusk, and maw—
'Ere we attained to human shape;
And ever as we fought we saw
The battle-chance, the battle-law.

And even now the æons' toil
The fruitage of the change and moil,
And agonies
Of centuries,
A wind can wreck, a worm can spoil,

And tiny cohorts of disease
Can rot half-ripe eternities.

. . . . . .

Creatures of Chance we live and die—
Chance is the Power we deify,
Whose wanton will
Squanders its skill,
Selects or slays, and knows not why;
What purpose can our birth fulfil
When purblind fates insanely kill?"

That is what Science seems at times to show, and we may ask whether Science has any moral or ethical or æsthetic value at all, and whether we should not regard Science merely as a convenient systematic manner of using and arranging facts to attain useful material ends—and whether we should not refuse altogether to mix up science and religion?

Personally, I hold that analytic science explains nothing, I hold that most scientific conceptions and interpretations of actuality are no truer, no more explanatory, perhaps less true, less explanatory, than the unscientific conceptions of the man in the street. A scientific man may imagine that he explains a rose when he analyses it into electrons, and that the scientific view of life is deeper than the view poetic. But it seems to me that the eye made by God is more truthful than the microscope made by man, and the view of the poet nearer the truth than the view of the physicist. Science is largely a process of abstraction and generalisation, and as Principal Iverach well said: "The process of abstraction and generalisation by means of which we seek to pass from the particular to the universal lead

us farther and farther from reality. Certain aspects are insolated. We take these qualities in which particular things resemble each other, and we neglect the differences, and we invent general names for the qualities they have in common. When the process is so far complete we are apt to substitute the qualities we have abstracted for the complex realities of which they are only aspects."

In the same way, Hugo Münsterberg concluded: "The truth of science does not express the reality we live in. Of course it serves our real life, otherwise it were an empty fancy, and it can be worked up from real experience, otherwise it were a dream. But it remains an artificial construction whose right and value do not go beyond the purpose for which it was fabricated." And more emphatically still, Du Bois Raymond affirmed the same philosophic proposition: "Und stumm und finster an sich d.h. eigenschaftlos wie sie aus der subjectiven Zergliederung hervorgeht, ist die Welt auch für die durch objective Betrachtung gewonnene mechanische Anschanung, welche Schall und Licht nur Schwingungen eines eigenschaftlosen dort zur wagbären hier zu unwagbären Materie gewordenen Urstoffes kennt."

All of which amount to much the same as Spinoza's axiom that "the more reality or being a thing has, the greater the number of its attributes," and certainly electrons have fewer attributes than roses. It is not the whirling electrons that explain the rose, but the rose that explains the flying electrons. Suppose a tribe of

men had eyes so powerful that they discerned leaves, and stones, and air, and all the matter of the world simply as whirling electrons. What an inexplicably horrible world it would be! But suppose some scientific man of their tribe discovered a way of lessening the power of the eyes, or of contracting the orbits of the electrons, so that stars, and roses, and birds, and men, and trees became apparent, what a wonderful explanation of all the inexplicable electrons it would appear. So again, if a tribe had ears that discerned the actual waves of air associated with sound, yet that could hear no sound, what a wonderful explanation of the waves it would seem if somebody were able to make the waves produce a blackbird's song!

Scientific analysis does not explain, and except for special purposes the knowledge it gives us is probably less true and less valuable than the knowledge given to us by our senses and emotions. A beautiful face or star has more meaning to us than any constellation of electrons; and the world of electrons is not a world of ultimate truth.

> "We boast the new world we have found
>   Yet in that world the roses fade;
> There is nor scent, nor light, nor sound
>   In the star-clusters we have made;
> We have but loosened and unbound
>   The broideries of beauty's braid,
>
> Have stripped the pearls and watched them melt
>   Like pearls in Cleopatra's wine;
> Yet still in far Orion's belt
>   A million braided jewels shine,
> And still in all things seen and felt
>   Is something holy and divine.

Tho' we have rent the cord in twain
  That gives the atoms shape and form
Till every rock grows misty rain
  And every star becomes a storm;
Yet still the sheaves in Charles's Wain
  Lie bound together ripe and warm.

Our soul is stormed by flower and star,
  Our ears a million songs assail,
Can we annul a rose, or bar
  The music of a nightingale?
Beside the light of things that *are*,
  The things of dream and vision pale.

Though with our dreams the world we drape,
  And with our laws the world explain,
For us there can be no escape
  From the sun's light, the lark's refrain.
Music and colour, sound and shape
  Besiege the heart, and flood the brain."

It is the synthetes that explain the analyts (if I may coin two words) not the analyts the synthetes. No analysis can explain a synthete, because every synthete, in the terminology of Lloyd Morgan, is a new "emergence" not to be anticipated from its antecedents—the synthesis is creative—eine schöpferische Synthese. In just the same way no individual processes of variation and selection and so on explain evolution, but the evolutionary product explains the processes. A compositor selects certain letters, e l e p h a n t, but it is the word that explains the selection, not the selection the word. The best, most important, most meaningful facts—meaningful in emotional as well as intellectual senses—are the large synthetic facts of consciousness, and science is merely provisional and ancillary.

To-day, indeed, Science is in some respects becoming

more and more shadowy (though useful) symbolism. When Jeans talks of stars so distant that light travelling at the rate of 186,000 miles a second takes more than a million million years to reach us, he is using words to which the senses and the experience can attach little meaning, and he might almost as well put X. When we are told that a single tiny cell may contain 8,640,000,000,000,000,000 atoms, and would have to be magnified a million million times before it could be seen through a microscope, we are using figures that even the imagination cannot make real. When we are told that electrons flash around their little orbits at the rate of 1400 miles every second, making about 7,000,000,000 revolutions in a millionth of a second, we are really in the region of mathematical abstractions, and infinitely far from concrete facts that can be sensuously grasped. Kant maintained that only such knowledge could be considered really attained as could be mathematically formulated, and Physics to-day has reduced matter and the phenomena of matter to mathematical symbols, much as Pythagoras reduced the world to number.

But symbols and mathematical formulæ do not really explain, they are merely useful usable abstractions from facts too complex to be handled and used in themselves, and Science to-day is mainly pragmatic, and there is no reason to consider its symbols and abstractions more truthful than concrete and sensuous apprehensions. Yet, despite its limitations and beyond its special practical utilities, and above its symbolism, Science has

to-day religious and philosophic relevances which have been unduly neglected both by men of science and by religious teachers. I maintain that though the various findings of the various sciences cannot be intellectually quite integrated, yet together they lead to great intellectual conclusions, and particularly to a belief in a *infinite ruling Mind*—an infinite Wisdom, "for when the mind of man looketh upon secondary causes scattered, it resteth in them, but when it beholdeth them confederate and knit together, it flieth to Providence and Deity."

We cannot, as we have said, grasp the figures used by mathematicians to measure space and stellar and interstellar mass; but, at least, we gain from them impressions of almost infinite distance, infinite mass, and infinite time. We cannot grasp the figures used by physicists to measure the orbits and the speed or the mass of electrons; we cannot grasp the relationships between the clashing of electrons in the sun and a grain of starch in an ear of wheat; we cannot conceive the nature of ether nor the enormous energy it contains; gravitation remains to us a mystery; but, at least, we realise that behind the universe as analysed by Science are mystery unfathomable, and power almost omnipotent.

We cannot understand the relation between the electrotonic structure of an atom or molecule and its chemical properties; we cannot imagine the infinitesmal size and lightning progression of waves or particles of light; but, at least, we can discern infinite

precision, and infinite delicacy, and results miraculous in their sensory and spiritual consequences. Astronomy, physics, chemistry, at least, are full of phenomena which fill us with a sense of wonder, with a sense of mystery—with a sense of the working of powers invisible—with, I think, a Sense of God. The big facts as represented, however abstractly, partially and symbolically, by these sciences yet are endeavours to find expression of tremendous things. And biology in its failure to find a mechanistic explanation of the mysteries of life, and in its discoveries of intricate relationships and ingenious means to ends, likewise compels us to believe in an Omniscient Mind. The effect is cumulative—each science by its own particular path leads us so far towards an intellectual and emotional apprehension of Infinite Power and Wisdom, and all together compel us to postulate a Providence.

Indeed, in the present state of scientific knowledge, Science, unless it postulate a God, ceases to be rational and scientific. In the last decades of last century, biologists believed that Darwin had solved the mystery of life and that mind was merely a by-product or an end-product of chemical processes—and even to-day some of those whose ideas were formed in those days still stick to their old beliefs. Quite recently a distinguished man of science, still under the influence of these decades, asserted that the belief "that mind or soul is a manifestation of the living brain is an accepted commonplace in medicine"; and stated also that "medical men then regarded soul as resident in and inseparable from

the highly organised living nervous matrix of the brain"; and that, "as far as biologists can perceive, the loom works automatically, the threads spin themselves."

Such materialism was natural in the light of the knowledge of the middle decades of last century. Looking back to which Bateson exclaimed: "How easy it used all to look! What glorious assumptions without rebuke!" But to-day—though of course there are exceptions—"Modern Science," as a great scientist, Millikan, puts it, "of the real sort is slowly learning to walk humbly with its God, and in learning that lesson it is, even as physics has learned the mystery of matter, contributing something to religion." To-day biology appreciates the mystery of life, and the mystery of evolution: it is no longer really confident of creating life in a test-tube, it is no longer accepted as a commonplace the absurdity that mind or soul is a manifestation of matter or that a casual selection of casual variations accounts for all living creatures: it is "learning to walk humbly with its God." The scientists now are becoming the mystics and it is the bishops now who believe that Science has solved life. "We have now," remarked Professor Dwight in 1911, "the remarkable spectacle that just when many scientific men are of accord that there is no part of the Darwinian system that is of any great influence, and that as a whole the theory is not only unproven but impossible, the ignorant half-educated masses have acquired the idea that it is to be accepted as a fundamental fact." If that spectacle

were remarkable in 1911 it is even more so in 1930, and in 1930 it is still to be seen.

The truth is that the more Science knows the more Science is compelled to recognise that the things that we see were not made of the things that do appear, that the only explanation of matter and of life is a God. "Halbes Wissen führt von Gott ab, grundliches Wissen führt zu Gott hin." "Half knowledge leads away from God, full and deep knowledge leads to Him."

Biologists may make a last effort to escape from the logical conclusion—God—by using such neutral terms as "determinants" and "teleology," but there is no escape. The hound of Heaven is steadily and tirelessly tracking them down. Study does not simplify cellular phenomena, it shows them more inexplicable, and more and more the functions of life are seen to involve environmental preparations and reciprocities and correspondences that cannot be explained by chance and that can be explained only by intelligent prescience or providence. "The mere making of the alleged mud into which was breathed the breath of life, was a tremendous yet delicate process requiring the power of the mighty Sun, the action of gravitation, the dynamic properties of gases, the chemical properties of water and carbonic acid, and a thousand things beside. The failure of any one of the long co-ordinated series of intricately co-operative factors — the absence even of the one electron that makes carbon—would have precluded the possibility of life. Nor can we assume that living matter once made would evolve under environ-

mental influences into the myriad forms of animal life, and into an elaborate system of nerves and nerve-cells capable of painting pictures and writing books, unless we also assume a pre-arrangement of chemical constituents and parts in the vitalised mud—a pre-arrangement of such a nature that its reactions with food, and air, and warmth, and the other elements of its environment would suffice automatically to produce all the animal and vegetable world. And surely such a pre-arrangement, such useful fateful correspondence—such amazing consequences inevitably following manifold contact with a multiplex environment must have been provided by an Omnipotent Mind. We cannot really escape from providence and the providential by a supposition of automatic chemical reactions, fortunate reciprocities, and lucky correspondences. It is simply by contact with environment that a harp makes music, but a mind made the harp-strings, and a mind arranged the varying digital environment. The variations and the environment that resulted in a man, whether after long evolutionary processes or not, must have been arranged, not by Chance, nor by blind Necessity, but by Omniscience.

" Yet was it Chance whose fumblings brought
Life from the burning cloud, and wrought
On Earth's cold crust
And lifeless dust
A living world with Beauty fraught ?
Chance ? Then in life and death we must
In Chance's wisdom put our trust.

The changeful light of human eyes,
The surgent seas, the sunset skies,

The starry throng,
The choirs of song—
If Chance wrought these then Chance is wise;
If Truth and Love to Chance belong,
Then Chance is fair and Chance is strong.

If Chance condense the dust afar
In myriad motions to a star,
If Chance can mould,
With pollen gold,
The silken seeds where lilies are,
If Chance one daisy can unfold,
Then God the hand of Chance must hold.

And though it seem a whirl of Chance
This ever-changing atom-dance
Of dust and wind,
Of brain and mind,
Of variant and circumstance,
Yet there must be a Power behind
Loving and strong, not deaf and blind."

It is not complicated antecedent processes we have to consider, but consequences and *results*, and though physiological and physical processes in themselves may seem anoetic as the movement of a river seems anoetic, yet if the consequences and results are the world as we know it—a world of beauty, a world whose rational existence depends on ingenious contrivances, and on elements, and parts that fit together as purposively and precisely as a million locks and a million keys, we are compelled to postulate a Creator—a Conscious First Cause—we are compelled to postulate a Maker's mind to account for the rational world even as we are compelled to postulate an author's mind to account for rational words.

In its crude form the argument from design cannot

be held—rabbits were not made to feed man. Yet in a more reasonable form an argument from design can certainly be held, and certainly points to a designing Mind—and to a very great designing Mind. Though rabbits and carrots were not made just to feed man, yet the relationship between food and oxygen and protoplasm—a relationship that means not only assimilation but growth, and repair, and activity—a relationship of a most intimate, most vital, most amazing kind with—and this is the point—*amazing consequences*, can hardly, I think, be explained as an accidental coincidence. If the mutton and potatoes Shakespeare ate were built up in his cerebral cells in such chemico-dynamic form as to produce a mind and a Hamlet, I hardly think we can explain such marvellous architectural consequences unless we postulate a Master Builder.

If we find that such relationships as subsist between the marvellous atoms of the mighty sun 93,000,000 miles away, and the intricate complicated chemistry of the chlorophyll of the green leaf, to the formation of carbohydrates, and if we find further that intricate and complicated relationships between carbohydrates and animal protoplasm are of such a kind as to result—through further intricate and complicated relationships—in all animal activities from the roaring of a lion to the eloquence of a Demosthenes. If we find an infinite and complicated concatenation of such intricate correspondences and reciprocities *resulting* in such things as human actions, and feelings, and thoughts, then I for one cannot escape from the conclusion that intelligent

prescience—an intelligent prescience that foresaw and pre-ordained the results—must have been at work.

Indeed, a thorough careful consideration of cause and effect, and of the intricate, and fateful, and fruitful correspondences in the processes of life must convince any clear-headed unprejudiced thinker that the results obtained by contact between living matter and its environment are just as purposive as the results obtained by contact between piano keys and a player's fingers—must convince him that the living matter was just as intelligently and presciently prepared to give forth the music of life under the touch of food, and sunlight, and air, as a piano is intelligently and presciently prepared to give forth music when touched by a player's fingers. Individual processes may seem to be explained by Secondary Causes, but the holistic behaviour of living bodies, the holistic integration of their structure, and the fruitful, effective reciprocity between their molecules—between their molecules and their environment—together *resulting* in the phenomena of life, compel us to postulate a creative synthesis—a primary conscious competent cause comparable in some manner with our own conscious connation when we purposively synthesise. The muscular explosions in the muscles of my fingers may seem as secondary causes to explain the movements of my pen, but the real cause—the cause of the integration of the movements into coherent meaning—is my will, and " the activity we feel when, through exercise of the will, we are ourselves causes best illustrates what is meant by causal activity. Carry this a

stage further, lifting it to a higher plane of thought, and we have the widely accepted belief that ultimately all observable change is due to spiritual activity."

Catholic Philosophy refuses to consider secondary causes without at least implicit reference to the First or Final Cause, because by doing so it would be dealing with incomplete concepts, and it seems a pity that men of science should not be similarly logical and philosophic. Primary Cause is not, as Sir Arthur Keith asserted, "a barren Virgin," it is a Vestal Virgin tending the flames on the altars of the soul: it is a Virgin Mary, Mother of God.

More and more, Modern Science—especially perhaps the sciences of astronomy and biology—has been demonstrating the mystery, the rationality, and the divinity of the universe, and yet most men of science seem still unwilling frankly to confess the great logical conclusions of their researches, still decline to allow the idea of a First Cause to influence their reasonings, and even when they use such words as "teleology," "purpose," "adaptation," try to evade the theistic implications of the terms.

Why is it? This theophobia is a comparatively recent affliction.

Almost all great men of science in past generations felt that science required the hypothesis of a God, and frankly said so. To-day, a few eminent men, such as Professor Arthur Thomson, admit that "as we cannot predicate purpose in a vast system, we must reverently ascribe it to a Creator." But as a rule God is kept as

carefully out of science as out of politics. Why, I ask again, is it ?

The reticence, the theophobia, is, I think, largely due to the narrow and restricted vision of distinguished specialists.

As we insisted in the first chapter, we can never discern the divine pattern of life if we study solely single threads of it. It is quite natural that an osteologist should see only the skeleton of life, and that the comparative anatomist should see only the slight differences between man and a monkey, and that a biochemist should believe it possible that living creatures are the result of chemical changes. These specialists focus their attention upon single physical facts, and, in the words of Driesch, " To see God in Life we must study linked constellations as small as atoms and as large as Orion's Belt."

Spencer suggested much the same idea, saying, " occupied with one or other divisions of Nature, the man of science does not know enough of the other divisions rudely to conceive the extent and complexity of their phenomena, and supposing him to have adequate knowledge of each, yet he is unable to think of them as a whole," but it is only by thinking of them as a whole that we can see their divinity.

And to the same effect is Francis Bacon's wise apothegm, " Certainly a little philosophy inclineth man's mind to atheism, but ' depth ' in philosophy bringeth man about to religion, for when the mind of man looketh upon secondary causes scattered sometimes it resteth in

them, but when it beholdeth them confederate and knit together it flieth to providence and Deity."

With the tendency to specialism there is a tendency, too, to compel the shoemaker to keep to his last, and any man who tries to be at once comprehensive and eclectic in his culture is distrusted and regarded with suspicion as a dilettante. But while it is necessary that certain minds should specialise, and while it is also certain that there are many minds that cannot fly further than the wings of a beetle, and cannot see further than the field of a microscope, it is also certain that to know anything well and to realise the wonderful weft of the world and the Fingers of its Maker, it is necessary to take long, high, and wide views, and every man of competent mind should endeavour, therefore, to see life from many sides, from the standpoint and through the eyes of many sciences.

It may be said that, in face of the enormous volume of scientific knowledge, it is impossible for a man nowadays to take wide views, and that wide views are shallow views. I do not believe it. I hold that there are certain problems that must be considered by every intelligent man—such problems as bear on the nature and growth of life, on the processes of heredity and evolution, on relationships between subject and object, on the probability of immortality, and that any keen mind, without becoming specialist, can acquire from each science the general facts relevant to these problems. "Biological truth if it is to be accepted," says A. Keith, "must be capable of complete demonstration to the

lay mind as well as to the professional." I hold also that it is especially the duty of clergymen to aim at wide culture—to think out things on large lines and not to accept the verdicts on big matters from narrow specialists, however eminent in their own particular departments the specialists may be.

Another reason why men of science ignore the theistic revelations of science is an idea which seems to me quite erroneous, that science should work entirely with the concrete, that science and theism must not be mixed, and that the great task of science—a quite impossible task—is to explain things without assuming the intervention of Mind. The idea that such an explanation is possible was greatly strengthened by the temporary success of Darwinian theory, and by the successes of organic chemists. If living things were the result of such chemical reactions as we see in a test-tube, and if all forms of animals and their adaptations were merely products of chemical reactions resulting in chance variations and luckily selected by the requirements of environment, there did not seem much necessity for a Divine Mind, especially as mind in man was assumed to be merely a manifestation of the brain, "resident in, and inseparable from, the highly organised living nervous matrix of the brain."

"We can demonstrate," said Haeckel, "the physical and chemical properties of the albuminous bodies to be the real cause of the organic or vital phenomena." "The aim of modern physiology," wrote Höffding, "is to conceive all organic processes as physical or chemical."

"In physiology," explained Burdon Sanderson, "the word Life is understood to mean the chemical and physical activities of the parts of which the organism consists." "It must not be supposed," said Huxley, "that the difference between living and non-living matter are such as to justify the assumption that the forces at work in the one are different from those at work in the other."

While these views prevailed, and while the forces producing carbon-dioxide and the forces producing a Macbeth were believed to be exactly of the same kind, there was no place for Causal Mind.

To-day, however, despite theophobia and an unreasonable reticence, these views of an anoetic mechanistic cosmos are less prevalent, overthrown mainly perhaps by physics and astrophysics, which have now broken down the distinction between the concrete and the spiritual, which have shown that matter is a mystery proceeding from invisibility into invisibility, which have indeed analysed the whole world into a product of invisible infinite power, and which have suggested even in physical processes a principle of indeterminism. Jeans, Eddington, and Lodge—three of the greatest physicists of the day—have given up mechanistic theories of the Universe.

Biology, under the influence of Darwinism, atomic chemistry, and mechanical physics, still clings to chemico-mechanistic explanation of life; but, as we have said, biologists are no longer so confident, and there is a strong tendency—not yet quite articulate—

to acknowledge a purposive Mind at the back of things. Lloyd Morgan says quite frankly, "For better or worse I acknowledge God as the *nisus* through whose activity emergents emerge and the whole course of emergent evolution is directed." Professor J. A. Thomson, in words we have already quoted, confesses that as we cannot predicate purpose in a vast system we must reverently ascribe it to a Creator.

In psychology, too, there is a strong trend towards a theory of life other than mechanistic, a theory of life, that is to say, which postulates—at least in living things—mind as an efficient causal factor. Professor M'Dougall, who is a leader of the anti-mechanistic school, holds that the matter of living organisms is brought under influences that are not to be found elsewhere, that these influences are mental and teleological and have not emerged from a mechanistic physical realm, and that even unconscious organic processes have a mental and teleological causology. From such a position to belief in a Divine Mind the step is easy to take, indeed almost inevitable.

On the whole, then, Science has progressed and is progressing from a mechanistic to a mento-creative theory of the universe. "Materialism of the cruder sort is no longer respectable." It seems to me, indeed, just a question of time and courage till Science frankly confesses that there is a Power at work in the world of life comparable with nothing save mind, and acting so wisely, so presciently, that it implies and signifies all we can mean by a Divine Mind.

The analysis of matter as achieved by modern physics; the enormous extent of the Universe as revealed by modern astronomy; the ingenious rational intricacy of the world of life in its structure relations and results as displayed by modern biological sciences—exhibit an infinitude of creative power and wisdom, and give rise to a cumulative emotional concept or belief in a God omnipotent, ubiquitous, omniscient. There is evidence of purposive Mind in inorganic as well as in organic processes, for otherwise the intricate and *fruitful* correspondences between living and dead matter—*e.g.* between volcanoes and the lung, between ether waves and the eye, between air-waves and the ear—could hardly have occurred.

"There are some men," as Cardinal Manning remarked, "who would rather commit intellectual suicide than acknowledge their Maker," and certainly only by committing intellectual suicide can any man of science to-day consider the wisdom of the human body, the wonder of the whole world of life, the inter-relations of things, and yet deny the workings of a Divine Mind.

"But one truth must ever grow clearer," wrote Spencer, "that there is an Inscrutable Existence everywhere manifested, to which he can neither find nor conceive either beginning or end. Amid the mysteries which become the more mysterious the more they are thought about, there will remain the one absolute certainty that he is ever in presence of an Infinite Energy from which all things proceed." That is virtually a confession of faith in a God; and the

late Principal Iverach, commenting on that statement, wrote: "We also have a right to assume a Power behind or within the chemical elements which will help us to account for the orderly and complex relations in which they exist. We are already acquainted with a power of that kind. We know intelligence as the source of order, we are acquainted with the way in which a principle of intelligence may be impressed on a number of efficient causes and cause them to exist as an intelligible system."

Let me clench my argument by a little story of Kepler—a story that more or less summarises my views. "Yesterday," said Kepler, "when weary with writing and my mind quite dusty with considering these atoms, I was called to supper, and a salad I had asked for was set before me. 'It seems then,' said I aloud, 'that if pewter dishes, leaves of lettuce, grains of salt, drops of vinegar and oil, slices of eggs, had been floating about in the air for all eternity, it might at last happen by chance that there should come a salad.' 'Yes,' says my wife, 'but not so nice and well-dressed a salad as this of mine is.'"

That is the gist of my thesis. Even granting, as I do not grant, that a world of sorts might have come by chance, I cannot believe that a world like this of ours—a world so knit together to produce marvellous results, a world full of living men and women—a world containing beauty, and wisdom, and love, could ever have come into existence without a Creative Heart and Mind.

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